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ILIAC-BONE TRANSPLANTATION

Preliminary Observations*

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Sir Arthur Keith tells that, in the summer of 1736, John Belchier, a London surgeon, ıs dining with a friend who was a calico printer. The main dish was a leg of pork and ělchier was surprised to see that the bone was red instead of white. Upon inquiry, he und that his thrifty host fed his pigs madder which had been used in calico dyeing. ělchier guessed that this might be the cause of the red staining, established the truth his surmise by experiment, and reported his findings to the Royal Society later that ar.[3] Thus the experimental study of bone growth and bone repair began.

Keith has also described the work of Duhamel in Paris, who, with John Hunter in ndon, Syme and Goodsir in Edinburgh, and Ollier in Lyons, continued the study during next century. The work of Ollier in particular, with his conception of the periosteum he "maternal tissue" of bone, had great influence on later workers.

In 1878 Macewen removed the whole diaphysis of the humerus of a three-year-old , whose osteomyelitis had persisted in spite of several less radical operations. Two later, the parents brought the boy back to Macewen for amputation of a limb h, though healed, was flail and useless. Macewen opened the arm and put a number edges from tibial osteotomies on other patients into the trough where the shaft of the erus had been. This is the first recorded example of the clinical use of homogenous -grafting. The length of the rebuilt humerus was six inches, of which four and one- f inches consisted of grafts. Twenty years later the man had an eleven-inch humerus, e inches shorter than that of the other arm, and was earning his living by manual k.

The result of this operation could not be explained on the basis of Ollier's theory, rom then on arguments about the fate of transplanted bone were added to the con- sy which already existed about the mechanism of normal bone growth and bone . These arguments and this controversy are still unsettled.

or twenty or more years Albee [1] stated persistently, and with considerable emphasis, ransplanted bone lives and grows in the same way that a transplanted twig grows tree into which it is grafted. He used this simile often, and he repeated it and his ve assertion about the survival of cortical bone grafts as late as 1944.[2] On the other , some surgeons have held with Leriche and Policard that transplants of cortical

* Read at the meeting of The British Orthopaedic Association, London, June 1, 1945.

bone always die and are replaced by cells originating in the host bone, and that such transplants form no more than a framework for the ingrowing bone.

Sufficient solid experimental evidence has now accumulated to show that neither of these conceptions of the fate of transplanted bone is correct. The work of Phemister, of Hey Groves, published in an essay which won him the Jacksonian Prize, of Campbell, and of Ghormley and Stuck,[8,9] shows beyond reasonable doubt what happens when the whole thickness of cortical bone is transplanted into another bone. Some of the bone cells of the transplant—those which are near the periosteal or the endosteal surface or in the more accessible Haversian canals—live and grow and form new bone. The cells deep in the dense cortical bone die, and this bone is replaced by new bone which grows either from the surviving cells of the transplant or from the cells of the recipient area. Imbert stated that this process is carried on in all parts but not simultaneously, so that a transplant examined at any moment shows dead bone with empty lacunae, as well as areas of living bone where the lacunae contain nucleated cells. That this is an accurate description of what happens to cortical-bone transplants is now widely accepted.

FIG. 1
Roentgenogram of ilium, showing the donor areas

It therefore follows that, while the strength and stability of cortical bone are often of great mechanical advantage in bone-grafting, this kind of bone may not be the best for the promotion of osteogenesis, for there are areas of bone in which the relative content of bone cells is very much higher than in cortical bone, particularly cortical bone from the tibia. Thus, if mechanical stability can be maintained by other means while the bone is healing and consolidating, it should be possible to make use of the superior osteogenetic properties of cancellous bone.

Experimental evidence supports this hypothesis. Campbell had repeatedly shown that cancellous, or endosteal, bone is the most ostéogenetic type of bone graft, and recommended its use when new-bone formation is most necessary, as in areas of greatest stress or in bone grafts for non-union. Gallie asserted that cancellous bone has much greater osteogenetic properties than cortical bone, and Matti produced further experimental evidence of this. Ghormley and Stuck published the results of extensive experiments on dogs, in which they compared the osteogenetic properties of bone transplants from various donor sites. They showed that, of all the known methods of bone transplantation, that which produced the most rapid and sure new-bone formation was the transplantation of cancellous bone chips from the ilium.

This observation is exactly in accord with physiological first principles. A transplanted tissue can continue to live only if it can derive nourishment from the bed into which it is transplanted. It therefore follows that the abundant bone cells in small pieces of cancellous bone, readily accessible to the ingrowing vascular buds, are much more

likely to live and grow in their new surroundings than the scanty cells of dense cortical bone. Compare, for example, how split-skin grafts thrive as free transplants, while grafts of whole-thickness skin need much more careful handling.

The damage done to the tibia, which provides the cortical transplant, must also be considered. Stress fracture of the donor tibia is by no means a rarity, and many patients complain of pain in the donor site long after the grafted area is healed and free of symptoms. Osmond Clarke has more than once said: "The more I see of the results of bone-grafting, the more loath I become to mutilate an intact tibia."

Chips of cancellous bone from the ilium are now frequently used by plastic surgeons in reconstruction of the contour of facial bones, and these surgeons report that clinical rigidity of the reconstructed area is obtained in seven days. The author recently helped a colleague to repair a skull defect, three inches by one inch in size, with iliac chips. When the sutures were removed from the scalp wound at ten days, the bony covering of the defect was already quite hard to finger pressure; indeed, only its irregular surface distinguished it from the surrounding skull. In 1944, Mowlem reported favorably to the Royal Society of Medicine on the use of cancellous chip grafts for the restoration of defects of bone, including the long bones.

The cases described are examples of the use of iliac bone in the bridging of bone defects, and in arthrodesing various joints. These examples, however, by no means exhaust the possible applications of the method.

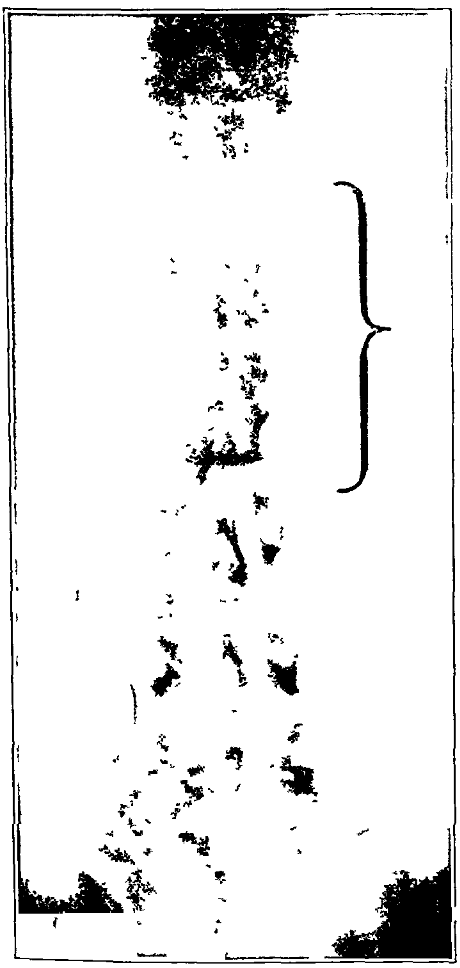

Fig. 2-A

Fig. 2-B

Case 1. Fusion of spine three months after operation.

Figure 1 shows that the two accessible areas in the ilium, where cancellous bone is most abundant, are: first, below the crest, just behind the anterior superior iliac spine; and, second, the posterior aspect of the ilium in the region of the posterior superior iliac

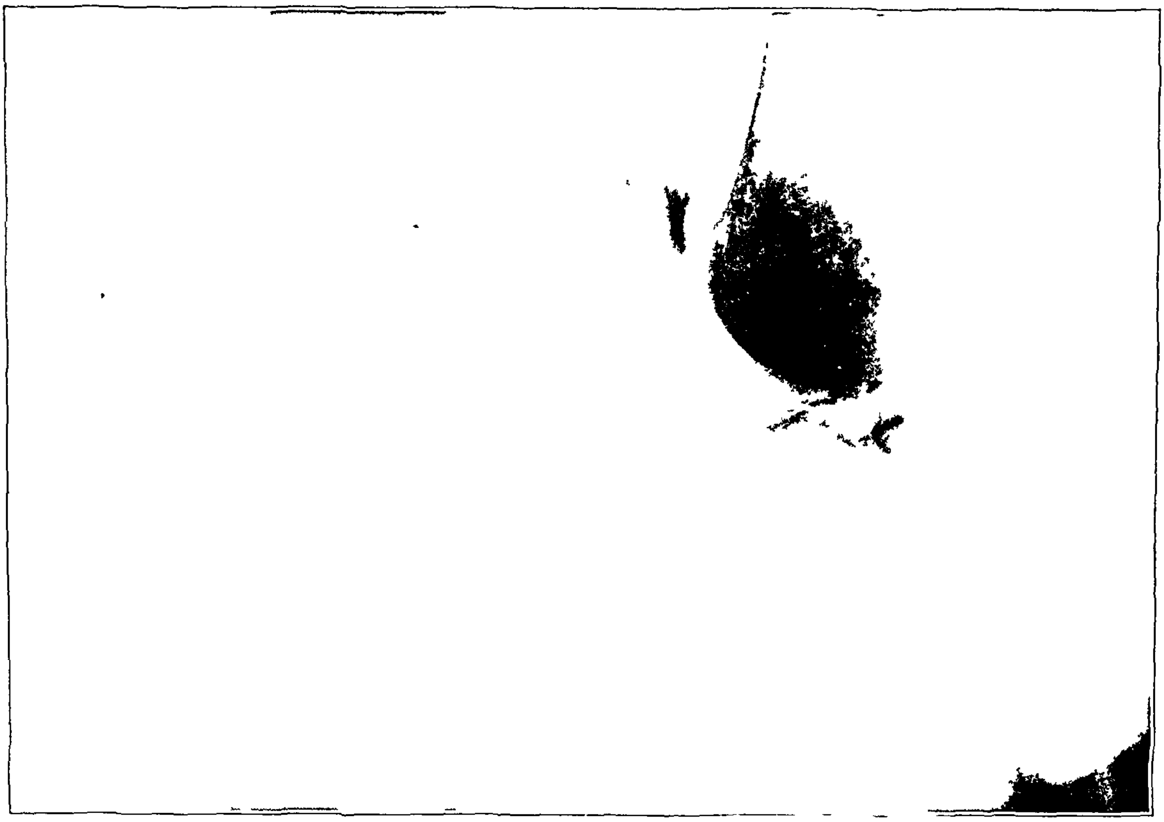

Fig. 3-A

Case 2 Showing lesion immediately after injury.

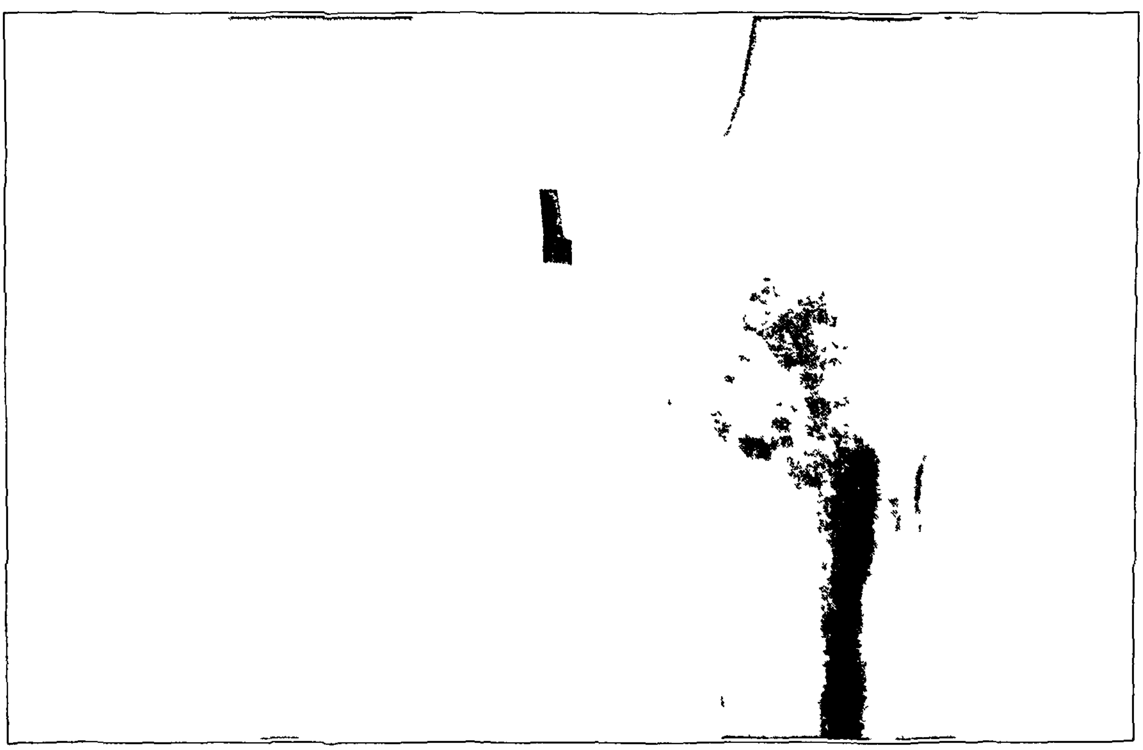

Fig 3-B

Eight weeks after operation.

FIG. 3-C
Twenty weeks after operation.

spine. Of the two donor sites, the latter provides by far the more abundant supply of cancellous bone. It should be used when a generous amount of bone chips is needed (as in fusion of the knee or in filling a tibial defect), even if it means that the patient has to be turned during the operation and therefore has to be draped twice.

The cancellous bone of the ilium is exposed by cutting a window in the outer cortex, by turning up the crest as a lid, or by combining both procedures; the choice depends on the amount of bone chips needed. The cancellous bone can then be cut out easily with a hand gouge. This method obviates any danger of penetrating the inner cortex. This is of importance in the posterior approach, because of the proximity of the sacro-iliac joint, and Oldfield has reported hernia of the caecum following the removal of part of the whole

FIG. 4-A

FIG. 4-B

Case 3. Subastragalar fusion.

Fig. 4-A: Twelve weeks after operation. Fig 4-B. Twenty weeks after operation.

thickness of the crest of the right ilium in front. The cancellous bone is cut into cubes, five centimeters on a side, or smaller.

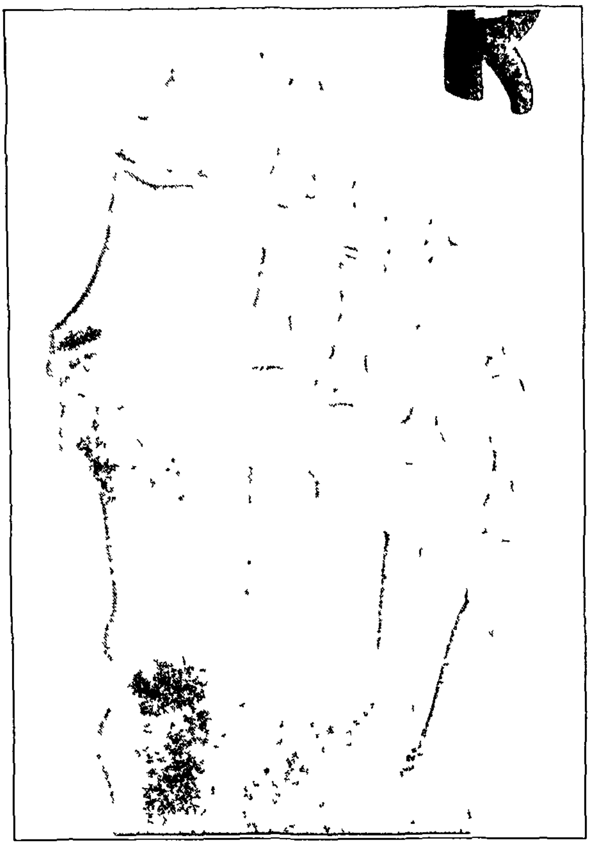

FIG 5-A
Case 4. Severe hallux rigidus before operation.

A hematoma forms more often in the anterior wound than in the posterior. In twenty-four posterior donor wounds there has been only one hematoma, and in eleven anterior wounds there have been three hematomata. More care is therefore needed with hemostasis in the anterior wound than in the posterior. The reason for the difference between the two sites in this respect is that a large muscle mass is cut in the posterior approach, and this, by its hemostatic effect, arrests the bleeding. The anterior crest is subcutaneous, and there is no natural local hemostatic. The importance of this point has only just been appreciated; with a little more care in hemostasis, hematoma formation in the anterior wound can be avoided.

The recipient area is prepared so that there is an immediate blood supply to the grafts. If a joint is to be arthrodesed, it is important not only to remove all the cartilage from the opposing joint surfaces, but also to open the cancellous bone at each bone end.

FIG. 5-B
Twelve weeks after operation.

Fig. 6-A
Case 5. Immediately after injury.

Fig. 6-B
Eight weeks after operation.

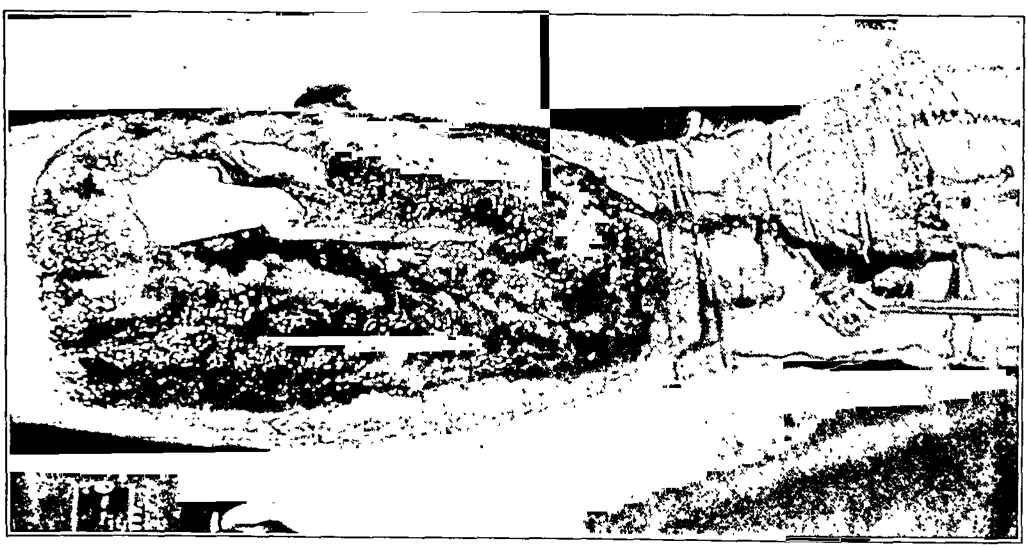

Fig. 7-A

Fig. 7-B

Fig. 7-C

Fig. 7-A: Case 6. Photograph immediately after injury.
Fig. 7-B: Roentgenogram soon after injury.
Fig. 7-C: Tibial defect after five months.

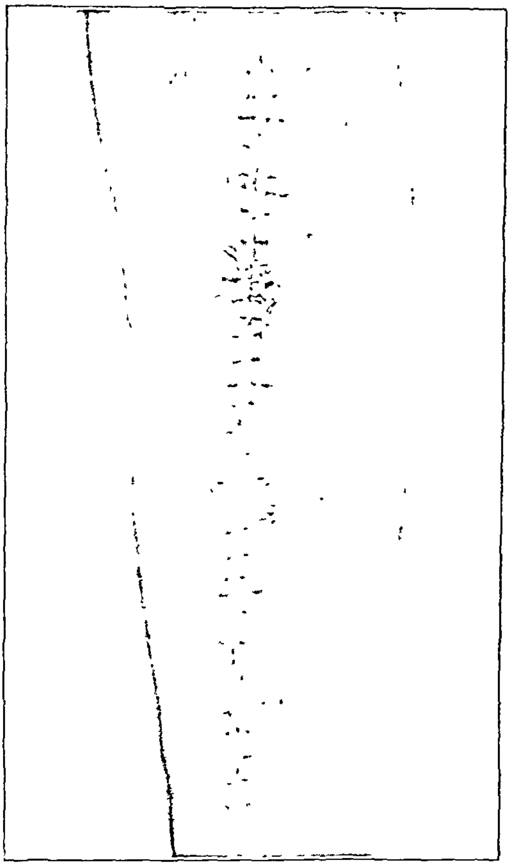

FIG. 7-D FIG. 7-E

Fig. 7-D: Scar of poor quality covering tibial defect.
Fig. 7-E: Incision through cross-leg flap, fourteen days after bone-grafting

If a bone defect is to be filled, the fibrous tissue between the bone ends, and the sclerotic bone ends themselves, must be cut away; healthy vascular bone above and below must be opened with saw cuts or by drilling; and the fibrous tissue covering the muscle bellies around the bone must be removed or incised. The cancellous bone chips are then packed into the cavity in the bone and around the shaft. Unless a rigid internal splint is used, the alignment of the limb is corrected by molding, during the application of the plaster. An advantage of iliac chips over rigid cortical grafts fixed by screws is that there is a second opportunity for manipulative correction of the alignment when the padded postoperative plaster is changed for a skin-tight plaster at the end of twelve to fourteen days. If any correction of alignment is needed, however, the change of plaster should not be delayed, for often by the fourteenth day, fusion is so advanced that the alignment can be altered only by the use of firm pressure, and it may be necessary to anaesthetize the patient.

CASE REPORTS

CASE 1. J. H., aged twenty-six, sustained a severely comminuted fracture of the body of the first lumbar vertebra when he jumped from an aircraft which had taken fire. The displacement was reduced by hyperextension in a plaster jacket, and a primary fusion of the twelfth thoracic vertebra to the second lumbar vertebra was made eight weeks later. The laminae of the vertebrae were rawed, the spines were rawed and split, and the whole area was packed with iliac chips. Figures 2-A and 2-B show the appearance after three months. Fusion was clinically solid, and there was no pain.

CASE 2. W. W., aged thirty-five, sustained a severely comminuted fracture of the tibial plateau in an aircraft crash (Fig. 3-A). It was decided that arthrodesis of the knee offered the only prospect of a

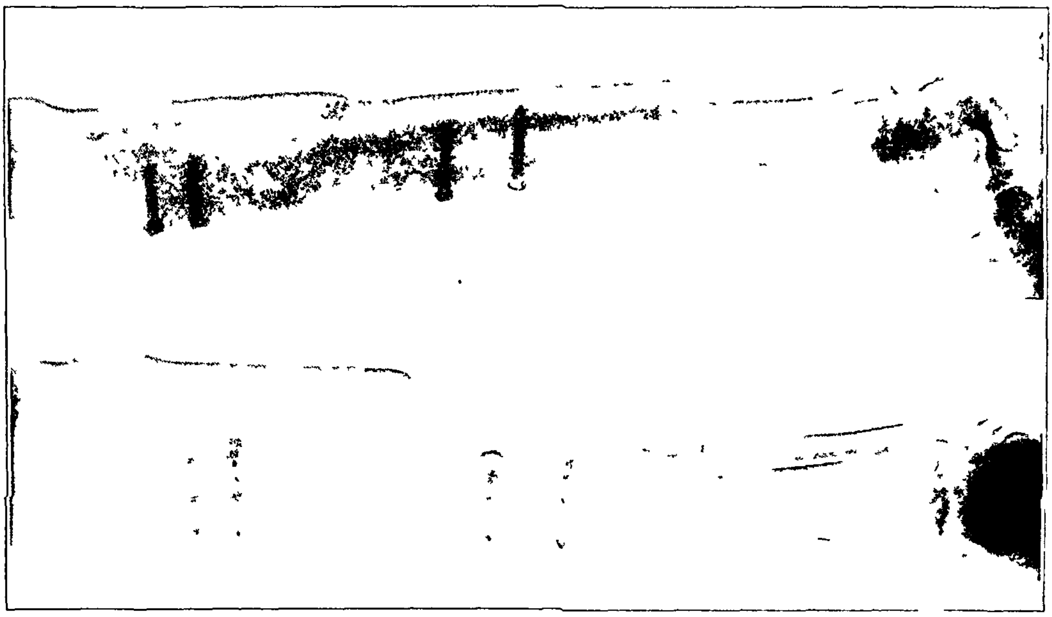

FIG. 7-H

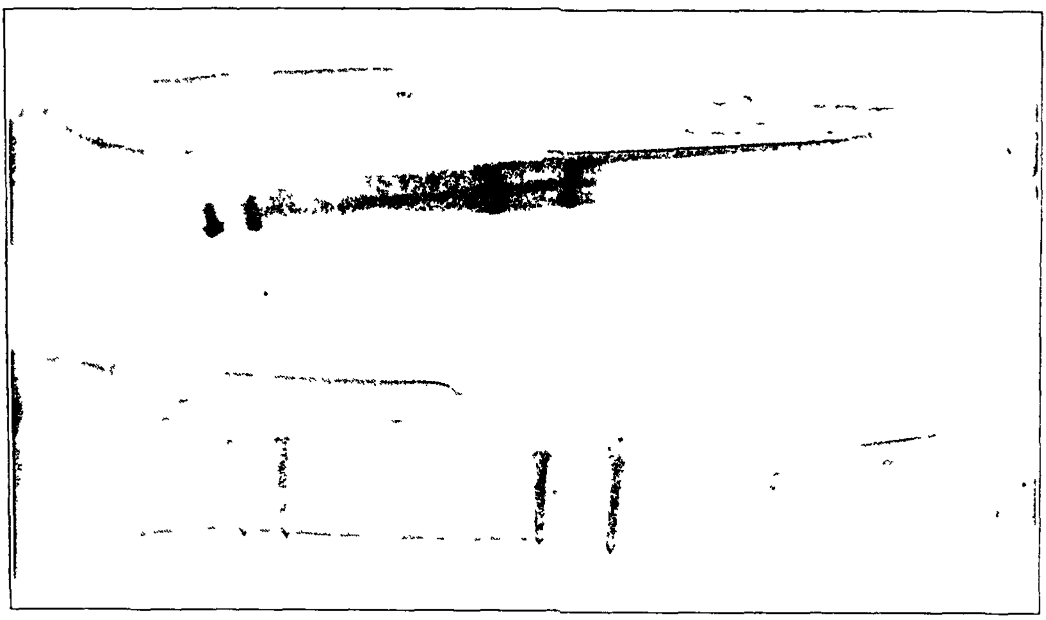

FIG. 7-G

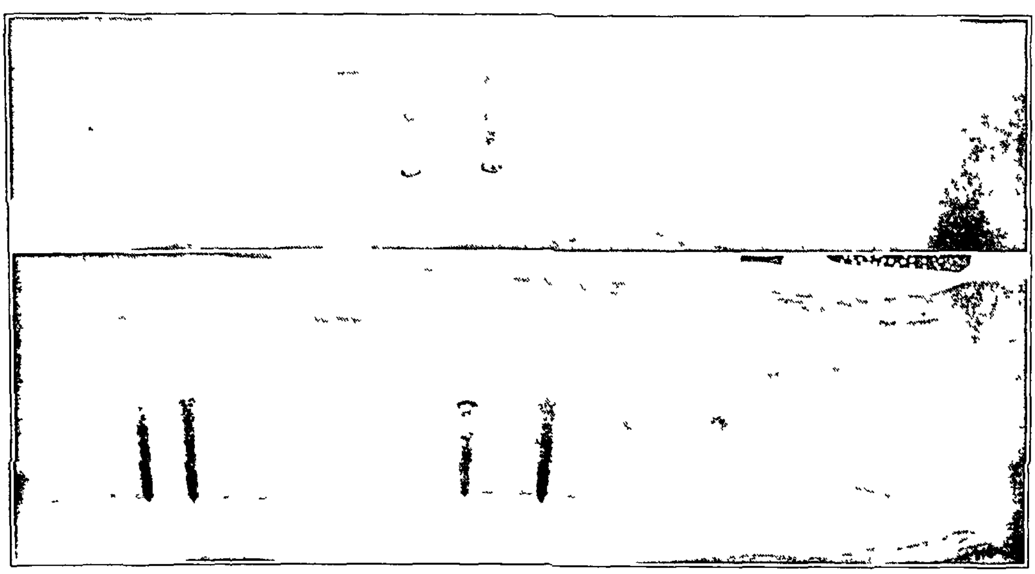

FIG 7-F

Fig 7-F Postoperative roentgenogram, showing tibial reconstruction.
Fig 7-G: Tibial reconstruction at twelve weeks.
Fig 7-H: Tibial reconstruction at thirty-six weeks.

painless stable limb. After a small associated wound had healed, the joint was excised and packed with iliac-bone chips. When the postoperative plaster was changed at twenty-one days, the joint was already firm. Figure 3-B shows the appearance of the joint, eight weeks after operation. The patient began to walk in a guarding plaster at ten weeks. Figure 3-C shows the appearance at twenty weeks; all external fixation had been discarded, and the fusion was solid and painless.

CASE 3. In R. S., aged twenty-three, the subastragalar joint was fused for painful osteo-arthritis, following a fracture of the os calcis. Iliac-bone chips were packed into a cavity cut in the back of the joint, through the posterior approach described by Gallie.[7] Fusion was clinically solid at twelve weeks (Fig. 4-A); Figure 4-B shows the appearance at twenty weeks. At that time the patient was free from symptoms.

CASE 4. In G. H., aged forty, the first metatarsophalangeal joint was fused for crippling hallux rigidus (Fig. 5-A). Iliac chips were packed between the denuded ends of the bones. At twelve weeks, the fusion was clinically solid and not tender, and the patient was walking comfortably in ordinary footwear (Fig 5-B).

CASE 5. H. R., aged twenty-three, an air gunner, sustained a fracture of the tarsal navicular in a cycle accident. When the immediate effects of the injury had subsided, the affected joints were excised and the area was packed with iliac-bone chips. At eight weeks the fusion was clinically solid and not tender (Fig. 6-B).

CASE 6. W. L., a twenty-one-year-old pilot, sustained severe compound and grossly comminuted fractures of the tibia and fibula (Fig 7-A). The wound was badly infected, and for some time there was considerable doubt about the wisdom of trying to save the limb. Ultimately, a large portion of the shaft of the tibia sequestrated and was removed, and the remaining wound was healed with split-skin grafts and pinch grafts. A large tibial defect was left, covered by a wide adherent unstable scar (Fig. 7-D). This scar was replaced by a cross-leg flap and later, through that flap (Fig. 7-E), the tibia was re-

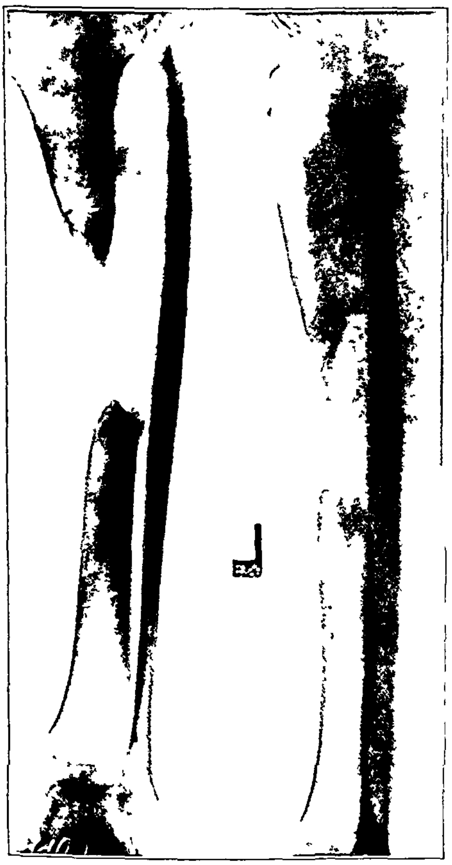

FIG. 8-A

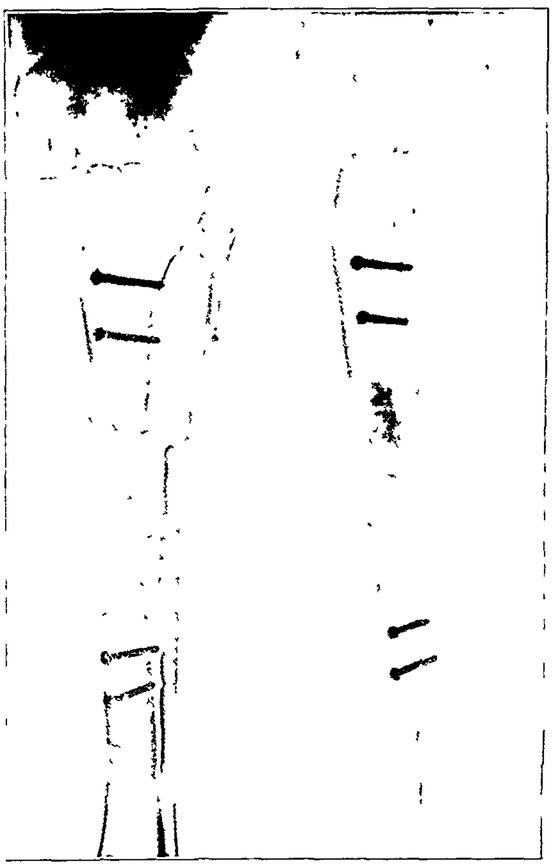

FIG. 8-B

Fig. 8-A · Case 7. Tibial defect, some months after associated wound had healed.
Fig. 8-B. Eight months after tibial reconstruction with cortical bone.

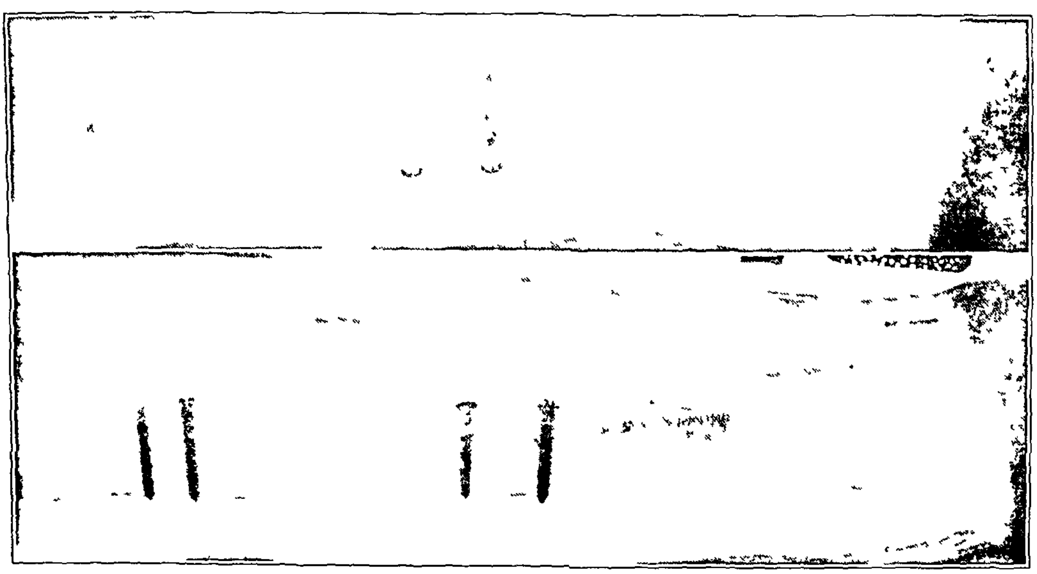

Fig. 7-F

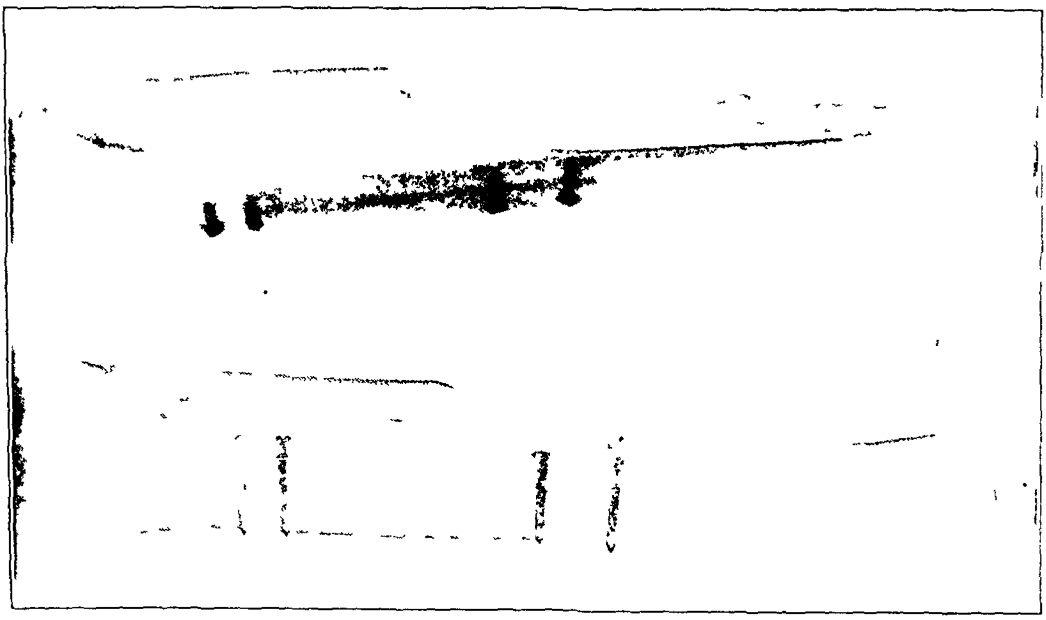

Fig. 7-G

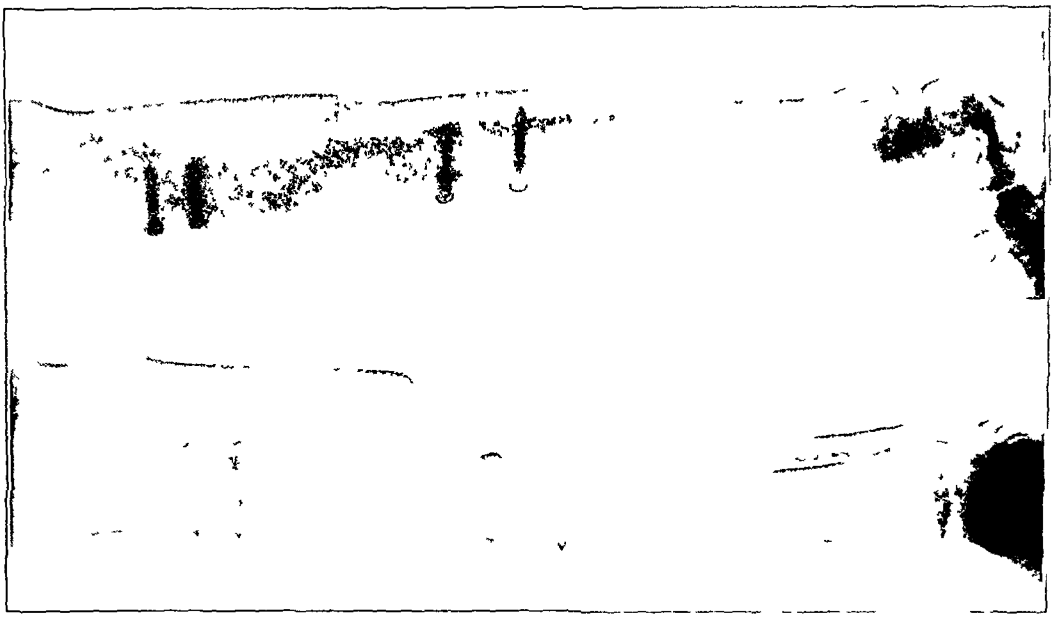

Fig. 7-H

Fig. 7-F. Postoperative roentgenogram, showing tibial reconstruction.
Fig. 7-G: Tibial reconstruction at twelve weeks.
Fig. 7-H: Tibial reconstruction at thirty-six weeks.

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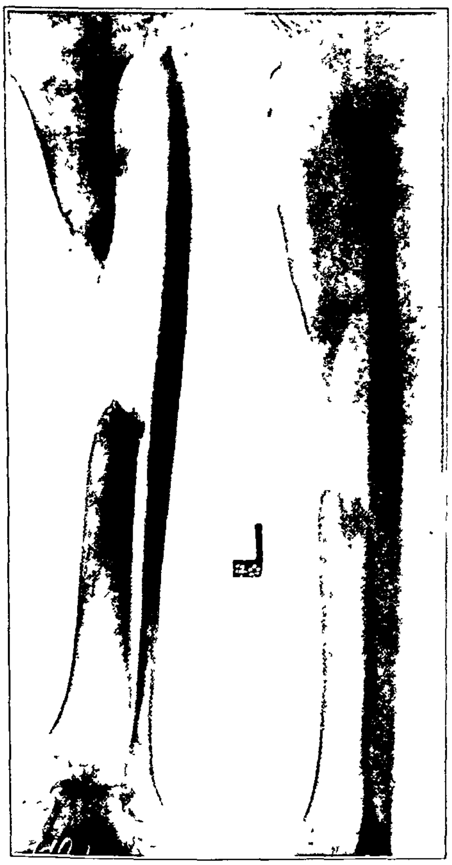

FIG. 8-A

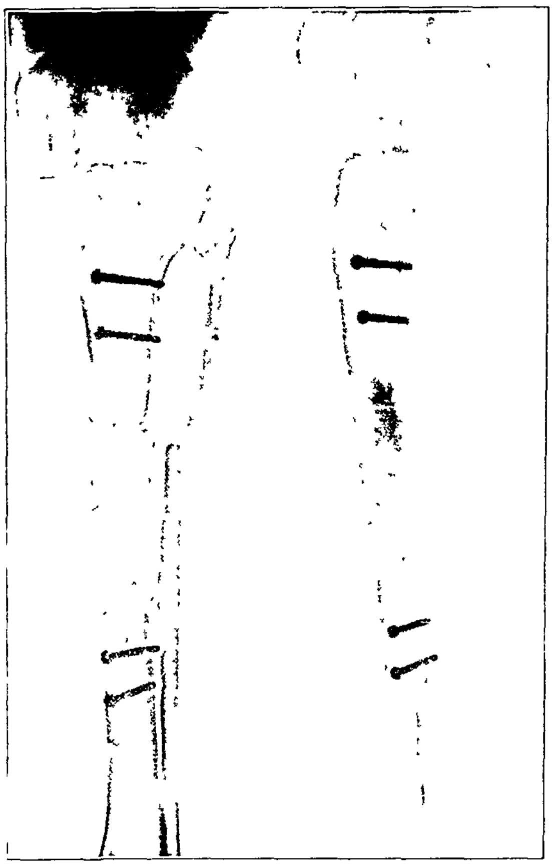

FIG. 8-B

Fig. 8-A: Case 7. Tibial defect, some months after associated wound had healed.
Fig. 8-B: Eight months after tibial reconstruction with cortical bone.

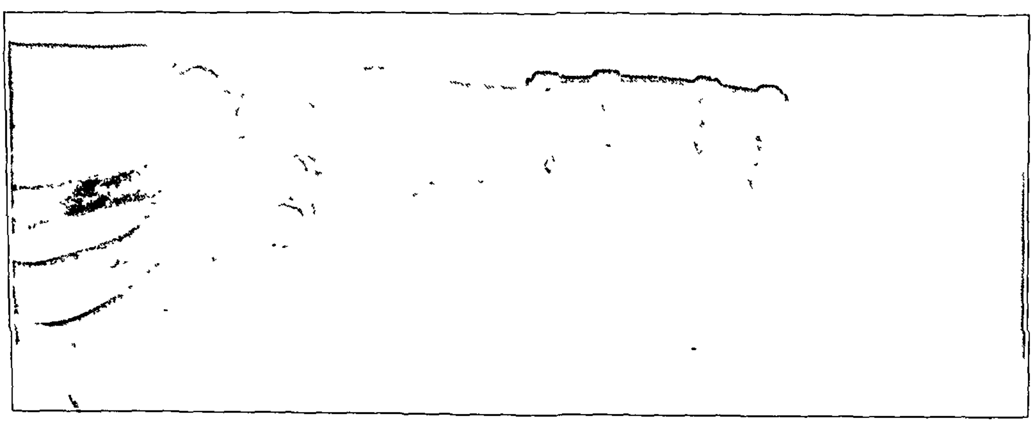

Fig. 9-A

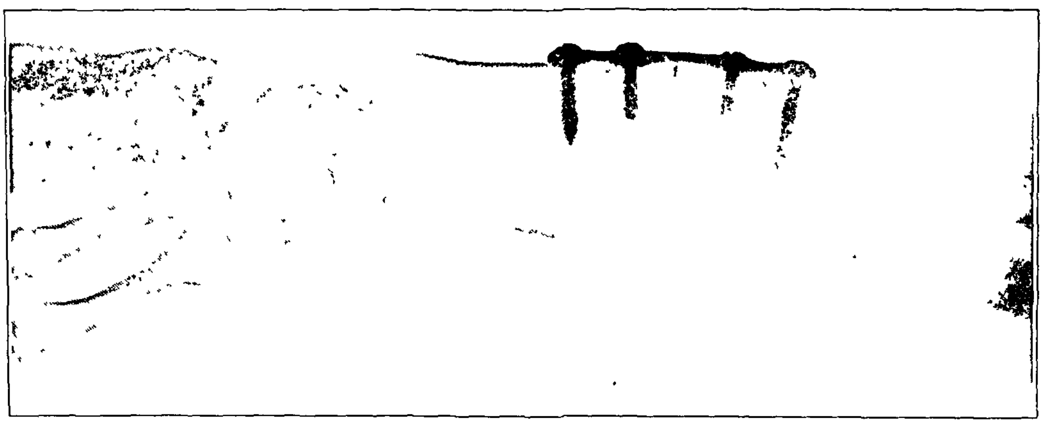

Fig. 9-B

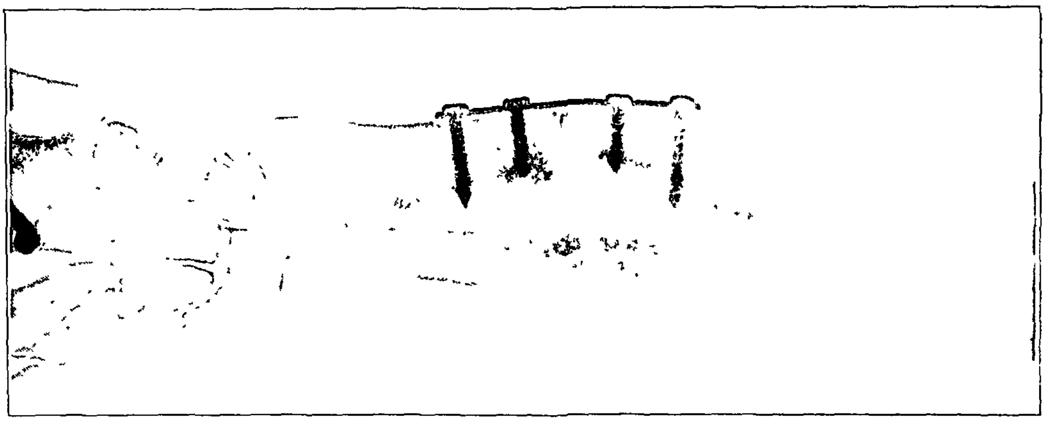

Fig. 9-C

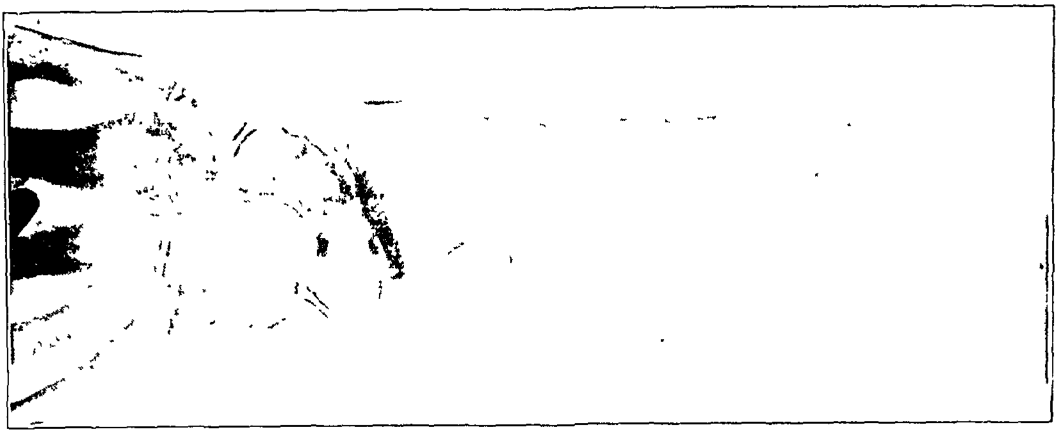

Fig. 9-D

Fig. 9-A: Case 8. Rotation osteotomy of radius, unhealed at twenty weeks.
Fig. 9-B: Eight weeks after use of iliac chip grafts.
Fig. 9-C: Sixteen weeks after insertion of iliac chip grafts.
Fig. 9-D: Removal of plate at twenty-four weeks.

built with twin cortical onlay grafts from the other tibia; cancellous bone from the ilium was packed into the defect (Fig. 7-F). At the end of twelve weeks the patient was exercising the limb in bed (Fig. 7-G), and three weeks later he began walking with crutches. A stress fracture developed in the donor tibia six weeks after the operation, and as a result the rebuilt tibia took unsupported body weight four weeks before the donor tibia. Figure 7-H shows the rebuilt tibia at the end of thirty-six weeks.

CASE 7. F. C., aged twenty-four, had a tibial defect (Fig. 8-A), which was very similar to that of W. L. (Case 6). The tibia was rebuilt (by another surgeon) with a massive onlay graft of cortical bone, and a piece of cortical bone to bridge the gap. Although the rebuilt tibia ultimately consolidated satisfactorily, it was still in plaster at the end of eight months (Fig. 8-B); at this stage, consolidation was poorer than in W. L. at twelve weeks (compare Figures 8-B and 7-G).

CASE 8. W. K., aged thirty-one, sustained a very severe fracture of both bones of the forearm, which united with overlap and poor alignment. The head of the ulna was excised in an attempt to restore rotation. When first seen by the writer, about six months after this operation, the fractures were soundly united and the patient had reasonable forearm movement, including nearly 90 degrees of rotation. The range, however, was from full supination to the mid-position, and the movement was consequently of less functional use than had the range been between the mid-position and full pronation. A rotation osteotomy of the radius was accordingly performed, pronating the lower fragment, and the bone was fixed with a vitallium plate. Twenty weeks later the osteotomy was quite unhealed (Fig. 9-A). The bone ends were then excised between the two central screws, the shafts were drilled thoroughly above and below, and the cavity cut in the bone was packed with iliac chips. Figure 9-B shows the appearance eight weeks later; at the end of sixteen weeks (Fig. 9-C), there was no doubt that the bone was uniting; and when the plate was removed, at the end of twenty-four weeks, there was solid union (Fig. 9-D).

Cancellous chip grafts are of value in the arthrodesis of joints, in the repair of bone defects, and in some forms of non-union or delayed union of fractures. A cortical graft may be needed to preserve the shape of a bone, but if stability of the fractured bone can be maintained by means other than the use of a cortical graft, cancellous chips alone will produce union. The main disadvantage of a tibial bone graft is that it usually has to be cut from an intact tibia. Plates and screws of absorbable plastic material, used with cancellous chips from the ilium, would appear to be the ideal method of osteosynthesis.

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THE USE OF CANCELLOUS CHIPS IN BONE-GRAFTING *

BY S. L. HIGGS, F.R.C.S., LONDON, ENGLAND

The principles and methods of bone-grafting have been well established for many years. In World War I and since, the results have been good, but the chief criticism has been that reconstitution of the bones has been slow.

It was, therefore, of the greatest interest to see a jaw which had been reconstructed in an incredibly short time by the use of chips from the crest of the ilium. The use of chips is, of course, not new, but the familiar tibial chips had but little osteogenetic power and could be seen as discrete fragments in radiographs taken long after the operation. The cancellous bone scooped out from the tibia was scanty and of poorer quality than cancellous bone from the ilium.

In order to explore the usefulness of these chips in orthopaedic surgery, seventy-one consecutive cases of bone-grafting have been reviewed, sixty of which were operations for non-union of the long bones. Of this latter group, cortical grafts alone were used in twenty cases, and cortical grafts plus cancellous chips were employed in forty.

All the operations have resulted in bony union, although in four cases the first attempt was not successful. One humerus, much of which had been destroyed in an air raid, was grafted three times, and another twice. In two cases of fracture, the tibae were grafted twice. In all four cases, the bones have now united. This refutes the opinion of those who believe that only a minority of bone-grafting operations are successful.

Complications were present in two cases, and in each the cause was the same. The operations were carried out through heavily scarred skin (one patient had had skin-grafting) and, owing to undercutting and tension, the skin sloughed at one point and the wounds did not heal, because of chronic infection. In both cases there is bony union, but further measures will be necessary.

Table I compares the healing time of grafts with cortical bone only and those with cortical bone plus chips.

TABLE I

Bones	Average Time of Union	
	Cortical Grafts Only	Cortical Grafts Plus Cancellous Chips
Humerus	16 weeks	8 weeks
Radius and ulna	17½ weeks	8 weeks
Tibia and fibula	17 weeks	8 weeks
Femur	22 weeks	14½ weeks

These periods of time cannot, of course, be stated accurately, but were based on clinical and radiographic evidence.

Of the eleven other bone grafts in the series, cancellous chips were used for filling bone defects or spaces. Five cases included an osteoclastoma, solitary cysts of the humerus and femur, and a case of osteitis fibrosa cystica. In six cases, chips were employed to hasten ankylosis in arthrodesing operations on the sacro-iliac, knee, ankle, and hip joints.

The method of taking chips from the iliac crest is illustrated in another paper.[1] It is of great advantage if an assistant can take the chips while the cortical graft is being removed from the tibia, as this saves time. The taking of chips adds to the length and sever-

* Read at the meeting of The British Orthopaedic Association, London, June 1, 1945.

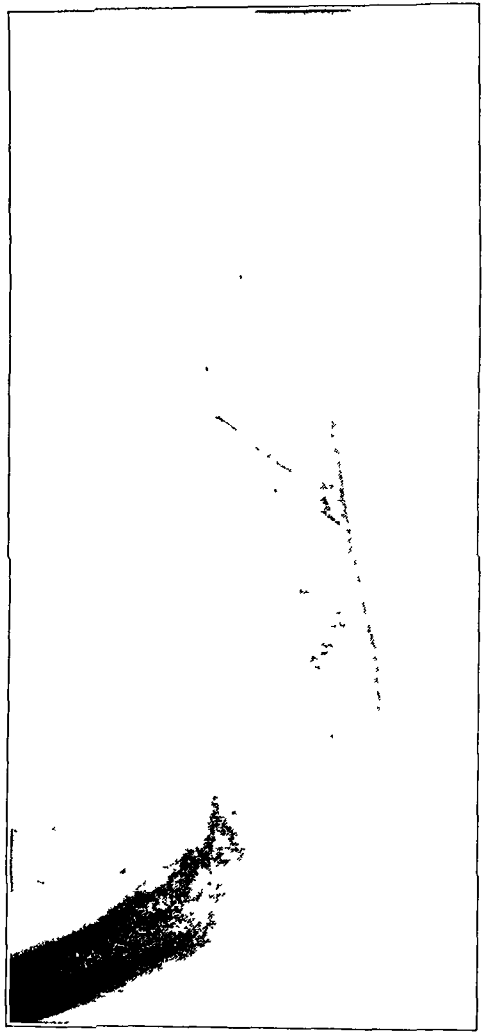

FIG. 1-A
Before operation.

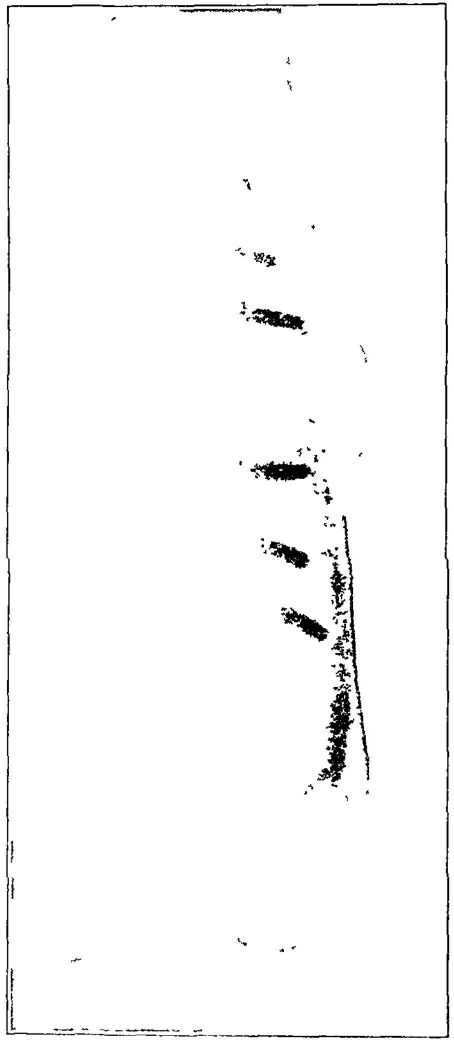

FIG. 1-B
After operation.

Fig. 1-B shows onlay cortical graft with cancellous chips, approximately six weeks after operation. Bone chips have fused, forming mass of new bone.

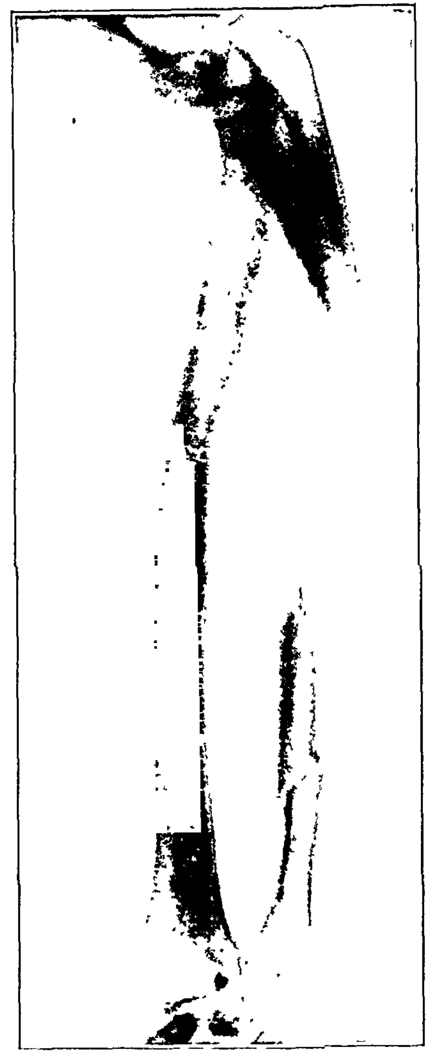

FIG. 2-A
Before operation.

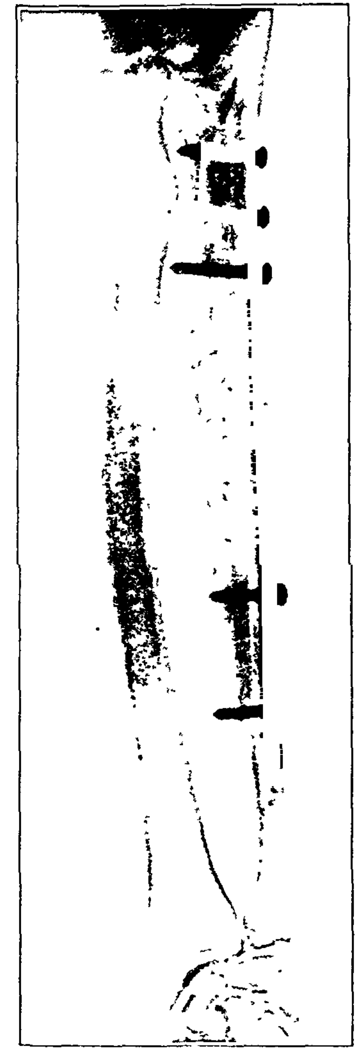

FIG. 2-B
After operation.

Loss of bone was due to gunshot wound. Defect was bridged by cortical onlay graft and chips. Radiograph approximately three weeks after operation shows individual chips still visible.

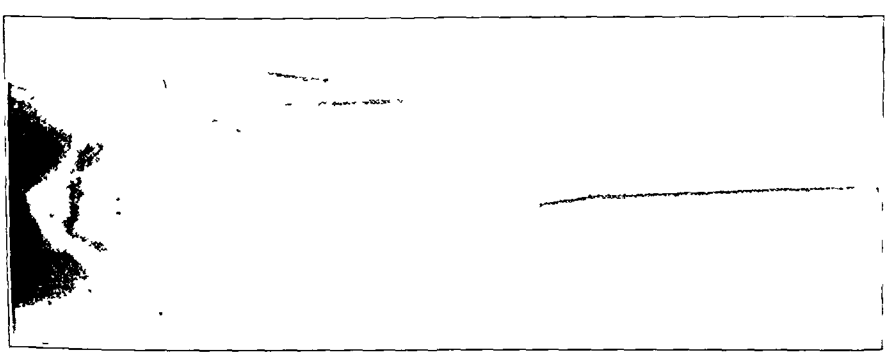

FIG. 3-A
Before operation.

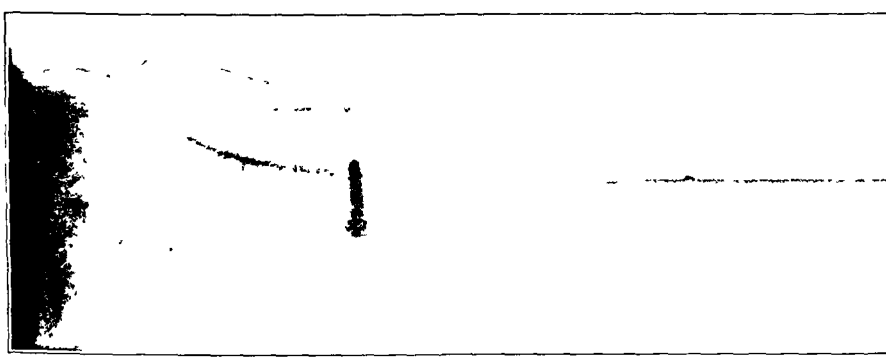

FIG. 3-B
After operation

Inlay graft was held in position by two vitallium screws. The more rapid growth of the cancellous chips in contact with muscle illustrates the importance of an adequate blood supply for the growth of cancellous bone.

FIG. 4-A
Before operation.

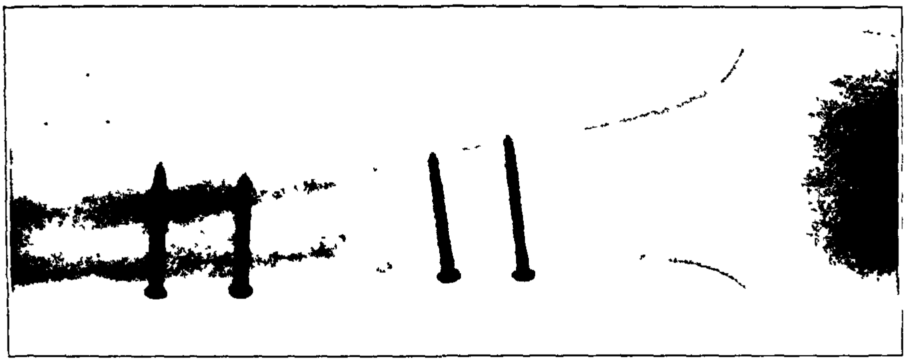

FIG. 4-B
After operation.

Fig. 4-B shows onlay graft with cancellous bone packed in and around fracture line after excision of sclerotic bone.

ity of the operation, but should not give rise to any serious anxiety. The iliac wound is a source of discomfort for only a few days. A drip transfusion of saline is given during the operation, followed, if necessary, by a blood transfusion.

For the use of cancellous chips to be successful, rigid fixation is necessary. To work through a window in a plaster, as has been done, adds to the difficulty and, even then, fixation is not likely to be very secure. To maintain length and alignment and provide immobilization, cortical grafts seem entirely satisfactory. The value of plates is less definite. The type of cortical graft depends upon the bone, and the following types have been employed: for the humerus, a screwed-on onlay; for the radius and ulna, an onlay or inlay; for the tibia, a sliding inlay or an inlay from the other leg; and for the femur, an onlay.

When chips are used to fill the gap, there need be no hesitation in removing all sclerosed bone. The chips are packed between the bone ends and around the fracture line, and often are kept in place by a guarding sliver.

To ensure a blood supply, all scarred and fibrous tissue must be removed; and, where possible, bare muscle should be brought into contact.

It is essential that the skin should be sound and not adherent. Bone is being added and it must be possible to bring the skin together over the increased bulk without tension. The help of the plastic surgeon in providing full-thickness skin has been invaluable.

Many of the cases reviewed had recently been septic, due to old gunshot wounds and bomb injuries. The rule of World War I, that a year must elapse after the end of all sepsis before bone-grafting should be undertaken, no longer holds. With penicillin and sulfanilamide powder, there should be very little trouble and no disasters.

In conclusion, the use of cancellous chips taken from the crest of the ilium has been found of decided value in bone-grafting. The chief advantages of this procedure are as follows:

1. In even "straightforward" cases, the chips will shorten, by approximately one half, the time required to produce firm union.
2. The chips, in conjunction with cortical grafts, are of great aid in filling gaps in long bones.
3. The chips are useful for filling bone defects, as, for example, after curetting cysts, and in packing the crevices and gaps in arthrodesing operations.
4. In the treatment of chronic osteomyelitis, the use of chips also plays a part.

1. Robertson, I. M., and Barron, J. N.: A Method of Treatment of Chronic Infective Osteitis. J. Bone and Joint Surg., 28: 19–28, Jan. 1946.

A METHOD OF TREATMENT OF CHRONIC INFECTIVE OSTEITIS *

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During the past few years, due to the introduction of penicillin and to the stimulus of war, there has been a gradual realization of the necessity for a revision of the treatment of such conditions as chronic osteitis. The pathological changes that occur in chronic osteitis are too familiar to require repetition, but it should be stressed that the bone and soft-tissue reactions to injury are intimately related, and must be considered together (Fig. 1).

In chronic osteomyelitis, the presence of sinuses and of superficial and deep fibrosis leads to a series of changes in the overlying skin and surrounding tissues, which result in permanent impairment of the vascular and lymphatic supply of the area. In chronic osteitis resulting from infected compound fractures and gunshot wounds, the effect on the surrounding tissues is incomparably greater; and the destruction of tissue by necrosis and suppuration leaves a dense, infected scar. It is thus rational that, in formulating any method of dealing with chronic osteitis, the treatment of infected and damaged soft tissue be considered of equal importance.

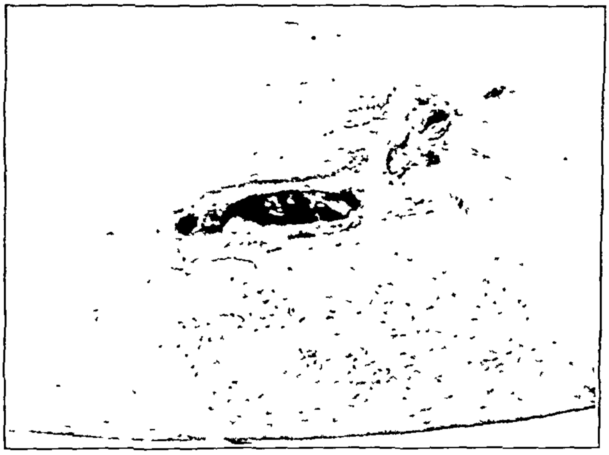

FIG. 1

The anterior internal aspect of the middle third of the left leg, showing multiple sinuses with skin adherent to underlying bone.

The principles and technique elaborated by Orr, and later applied in slightly modified form by Trueta for the management of war wounds, have now become the generally accepted methods of treatment for chronic osteitis. Under this regimen, the wounds are saucerized and then packed; healing by granulation tissue and scar epithelium is encouraged, drainage and splintage being maintained by the closed-plaster technique.

SUGGESTED TREATMENT OF CHRONIC OSTEITIS

The treatment is based on the principle of extensive excision of all diseased tissue, including skin, deep scar, and infected bone; and the replacement of soft-tissue defects by muscle and skin flaps, and of bone defects by bone transplants. The aim is to remove the whole of the local disease and to establish normal conditions in the tissues. This requires either two or three operative stages, as follows:

Stage 1: The excision of all diseased tissue and the application of a split-skin graft to the wound surface (Figs. 2 and 3).

Stage 2: The plastic repair of the soft tissues. The split-skin graft is removed and the area is covered by a skin and subcutaneous-tissue flap, muscle being included where necessary.

Stage 3: The repair of the bone defect (Fig. 4).

In some cases, Stages 2 and 3 can be combined. An interval of four weeks should be left between the first and second stages, and at least six or eight weeks between the sec-

* Read at the meeting of The British Orthopaedic Association, London, June 1, 1945.

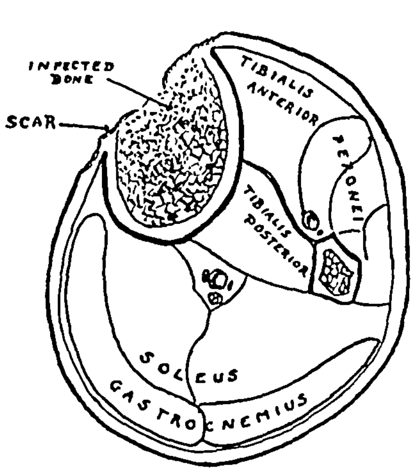

FIG. 2

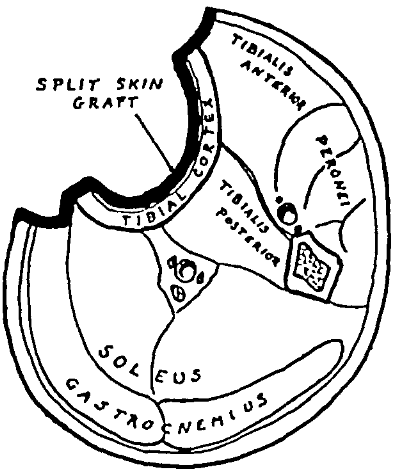

FIG. 3

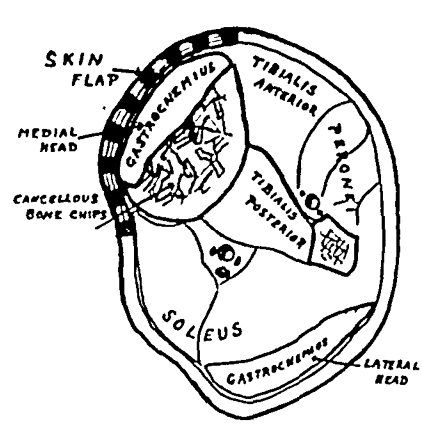

FIG. 4

Fig. 2: Diagram of area of chronic osteitis with overlying adherent, scarred, and ulcerated epithelium.

Fig. 3: Diagram of first stage of operative treatment. All scarred and infected soft tissue and bone are excised, and the area is covered with a split-skin graft.

Fig. 4: Diagram of second and third operative stages. Bone defect is filled with cancellous chips; soft-tissue defect is covered with muscle and full-thickness skin flap.

ond and third stages. Penicillin is used for twenty-four hours before operation at each stage, and is continued for four days after operation; 100,000 units each twenty-four hours are given by intramuscular drip.

This cannot be considered as a method of treatment for chronic osteitis in general. In the cases selected, the infected area should be accessible to surgical approach, and the site and extent of the disease should be such that a complete excision of this area is possible.

While the lesions of chronic bone infection are essentially the same in the upper and lower limbs, the surgical difficulties associated with the repair of wounds affecting the lower extremities are considerably greater. The majority of the patients already treated by this method have been cases of chronic osteitis of the leg,—the result of hematogenous infection, infected compound fractures, or gunshot wounds.

Stage 1: Extensive Excision of all Infected Bone and Scar Tissue, and Split-Skin Dressing

For the first part of this operation an Esmarch bandage should be used.

Skin: Excision of sinuses with adherent, infected, and scarred areas of skin must be complete. The skin flaps are not undercut more than is necessary to give adequate exposure of the whole infected area, thereby not only limiting the risk of exposing uninfected regions to contamination, but also minimizing the chance of endangering the blood supply of the skin. An atraumatic technique is of particular importance, because of the already diminished blood supply.

Soft Tissues: It is of the utmost importance that, while preserving intact all vital structures such as nerves and blood vessels, the dissection of scar tissue be as complete as possible and extend into healthy vascular tissue. Thus further infection can be reduced to a minimum, and an adequate blood supply can be obtained for future surgical procedures.

Periosteum: Similarly, normal unscarred periosteum should be left intact as far as possible, and should be handled with the greatest care. Periosteal stripping should be limited to that required for access to the diseased areas.

Bone: Systematic removal of diseased bone is essential. It is usual to commence at one end, and to cut away, layer by layer, the whole of the affected area until a smooth open surface of normal vascular bone remains (Fig. 6). This entails the complete effacement of all cavities, even if normal bone has to be sacrificed, and includes the removal of all sequestra and necrotic tissue. The exception to this rule will be found in defects in-

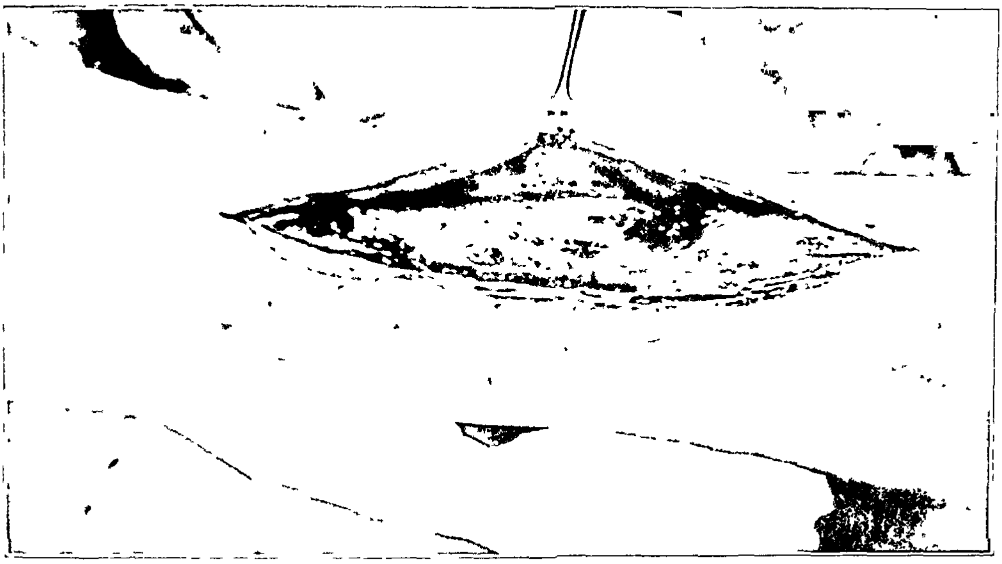

FIG 5
Scarred and infected soft tissue has been excised, exposing full extent of infected bone

volving the extremities of the long bones, where saucerization may be impossible, owing to proximity of the joint surface.

In compound fractures, it is frequently found that the infective process has involved the full diameter of the shaft, and indeed may have extended to the soft tissues beyond. These fractures usually fail to unite, and the wound becomes a chronic abscess cavity, two sides of which consist of bone faced by infected fibrous tissue. Bone removal should proceed to an oblique resection of the ends, cutting back until normal structure is revealed. This will provide access to the scarred periosteum and to the muscle which forms the deep wall of the infected area.

In cases where a bridge of osseous union is found, in spite of continued infection, a decision must be made as to whether the bony bridge is sufficiently vascular to be allowed to remain. This decision is of great importance and, with the bone-grafting methods to be described, there should be no hesitation in sacrificing bony continuity when that procedure seems wise.

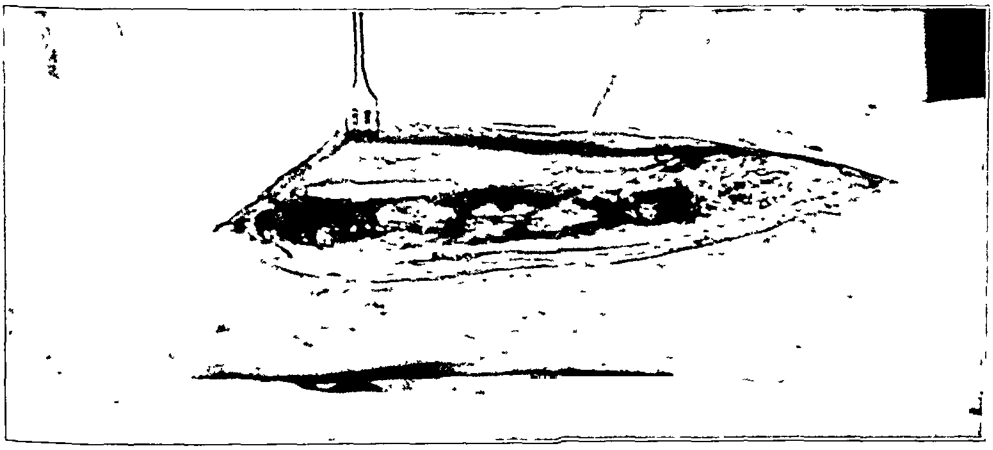

FIG 6
Area of bone excised during first operative stage.

Split-Skin Grafting

Contrary to widespread belief, split-skin grafts can be expected to survive in the presence of infection of the recipient area. The survival and growth of the transplanted tissue depends upon the surgical technique employed, and upon the use of chemotherapy. Furthermore, as the illustrations in this paper demonstrate, there is no doubt that cortical bone is a suitable temporary host for the grafted epithelium. The skin dressing protects the bone and surrounding soft tissues from the effects of infection and scar replacement. Thus it ensures the integrity of the remaining muscular tissue and the vascular supply, and so increases its resistance to infection. As a result, the reconstructive procedures can be completed at an early date without undue risk of reinfection.

1. Preparation of the graft bed: The tourniquet is removed, all large vessels are carefully picked up, with a minimum of surrounding tissue, and are tied with 6-0 plain catgut. Small oozing points are grasped with fine hemostats, which are allowed to remain on for a few minutes. The wound is then packed with a hot swab and the limb is elevated until the general surface weeping ceases. A little patience is necessary, as five minutes may elapse before the bed becomes really dry. This period may be spent in cutting the skin graft, if the opposite thigh is to be used for this purpose.

When the leg is again lowered to the table, the only surfaces which may continue to give trouble are the cut bone ends. An effective procedure is to cover them with small swabs saturated with thrombin (in a strength of 500 units per cubic centimeter) and to apply pressure for a further period. When the swabs and hemostats have been removed, the whole wound surface should be ready to receive the skin.

2. Application of the skin: A thin split-skin graft of sufficient size to cover the wound is cut and spread out on tulle gras or vaseline gauze. It is punctured in several places with a knife, so that drainage from the wound surface can be absorbed into the dressing. The

Fig. 7-A

Fig. 7-B

Fig. 7-A: Roentgenogram of gunshot wound of upper third of tibia, showing large cavity which was partially filled with infected scar tissue and granulations, with surrounding necrotic and infected bone.

Fig. 7-B: After excision of all infected tissue.

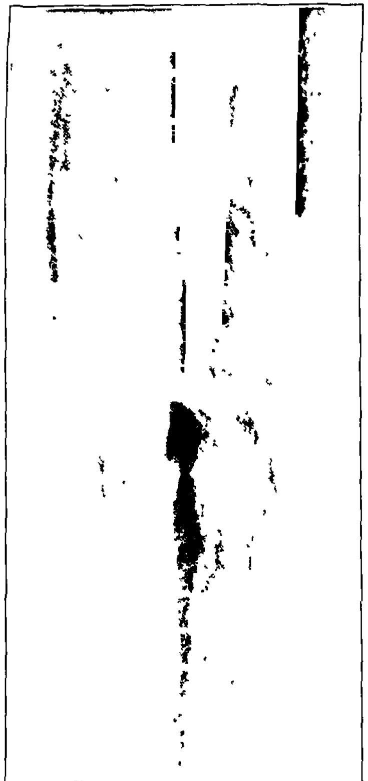

FIG. 8-A

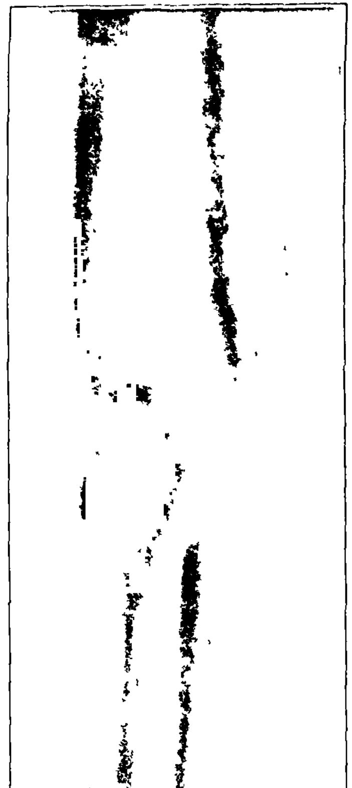

FIG. 8-B

Fig. 8-A: Roentgenogram of compound fracture of tibia which had been plated, and subsequently became infected. Note large area of necrotic bone with central sequestrum.

Fig. 8-B: After first stage in treatment. Note extent of bone excision required, and new-bone formation in fibula.

FIG. 9-A

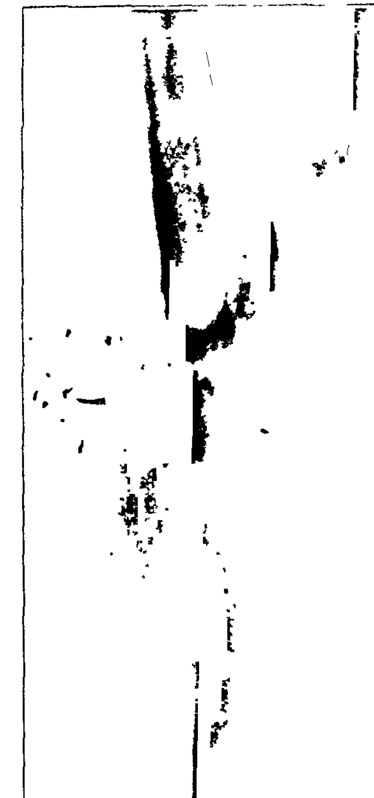

FIG. 9-B

Fig. 9-A: Roentgenogram of gunshot wound of tibia with probe leading down sinus to necrotic bone with central sequestrum.

Fig. 9-B. Note extent of bone excised.

wound is then lightly dusted with penicillin powder, the graft is laid on, and pressed down into the contours. The skin and tulle gras are stitched to the wound edges, the ends of the sutures being left long enough so that they may be tied over the dressing as an aid to immobilization. Wool wrung out in normal saline is packed down over the graft, so that an accurate mold is made which will distribute pressure equally over the whole area when a bandage is applied. The long sutures are tied over the wool mold, the limb is encased in wool, and bandaged with an elastic bandage, firm, even pressure being used. A light plaster cast is applied over all.

Postoperative Care

After the operation the limb is elevated, but receives no attention for two weeks It is then dressed for the first time, when it may be either healed or there may be patchy failure of the graft. In our experience an 80 per cent. "take" of the skin was the poorest result, and the average was about 90 per cent. Loose skin tags and desquamating surface epithelium are cut away and the graft is thoroughly washed. It is then painted with 10 per cent. mercurochrome and a further dressing is applied, similar to that used at operation, except that no sutures now remain. A plaster back splint is retained, and no further interference is required for a week. Then the massive dressings are discarded, exercise therapy is instituted, and the wound is dressed every second day. Any remaining granulations are painted with mercurochrome and covered with a light gauze pack; epithelialization is usually complete within ten days.

FIG 10

Stage of excision completed Split-skin graft lining cavity and covering bone Skin graft "take" complete in four weeks

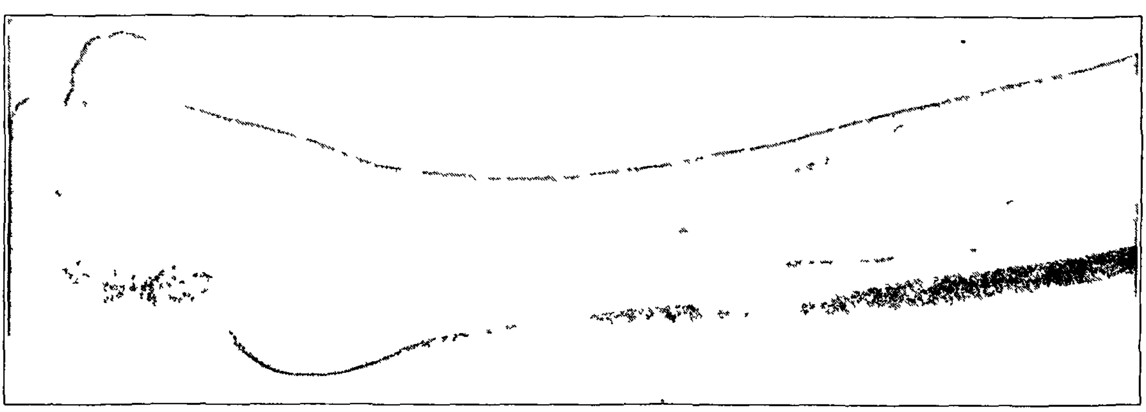

FIG 11

Second stage completed (see Figs 8-A and 8-B) Cross-leg flap covering bone defect

Stage 2: Repair of Soft Tissues

At this stage we are faced with a composite defect in the limb, consisting of loss of bone, muscle, subcutaneous tissue, and skin. The ideal to be aimed at is replacement by similar tissues. The main problem is the provision of a stable scar-free skin cover. The split-skin graft has done its work as a temporary dressing, but being for the most part based on bone, it is too vulnerable. It must, therefore, be replaced by a viable flap of skin and subcutaneous tissue; but it should be remembered that it is difficult to design a flap to fit a concavity. A dead space is disastrous.

Where the depth of the bony cavity is such that no skin flap can be designed to fit it, use is made of muscle flaps and cancellous iliac bone to fill the defect, over which complete skin closure can be obtained.

Types of Skin Replacement

1. Local plastic operations

The *rotated* flap is ideally suited to fill a triangular defect. It is designed on generous lines and is based proximally. Allowance must be made for the fact that it is not being used on a flat surface, but around the circumference of a limb (Fig. 11). Any secondary defect that is left after the flap has rotated should be arranged to lie over the posterior calf muscles, where a split-skin graft will be satisfactory. Tension should not be relied upon to effect closure.

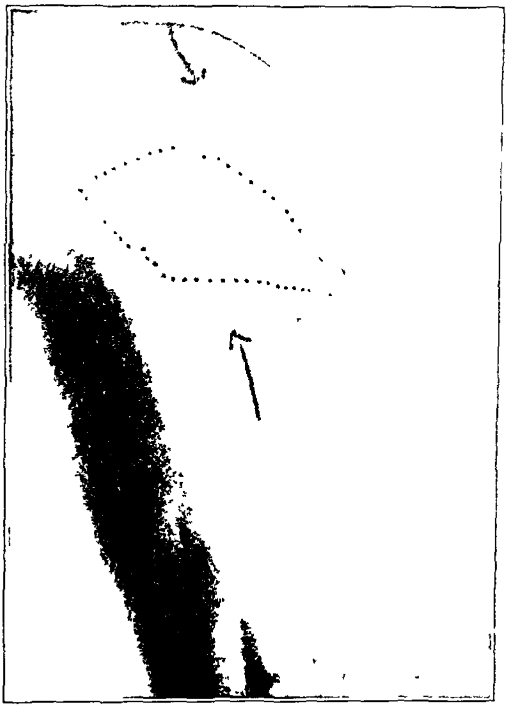

FIG. 12

Second and third stages combined. Double-rotation flaps used in repair of skin defect, which is indicated by dotted line.

The *transposed* flap is cut of the pattern of the wound and transposed on a pedicle from a suitable aspect of the limb, leaving the secondary defect in a position where it can be grafted.

The *bridge* flap has a double base and is raised as a strap. Its movement is limited and depends mainly upon stretch and the elasticity of the skin. It is best suited to fill elliptical defects, where maximum closure is required in the center of the wound.

Local plastics on the leg are fraught with difficulty and there are certain limiting factors. The blood supply of the skin, notoriously poor at best, is often very much depleted in an atrophic limb which has been lying for months encased in plaster. Cutting a flap still further embarrasses the circulation to the area, and every allowance must be made for this.

The transverse width of the wound indicates whether a local plastic should or should not be used. A defect measuring more than two inches across should be carefully considered before the decision is made to repair it locally, but usually it is better to import skin from elsewhere.

The surgical procedure of "delaying" a flap gives a margin of safety in doubtful cases. The flap is outlined and undercut, then sewed back into position. This encourages an augmented blood supply through the base, and ten to fourteen days later the flap can be rotated or transposed with safety.

2. Repair from a distance

The *cross-leg* flap is the most satisfactory method of importing skin. The legs are apposed in such a position that the defect to be covered is approximated to the upper half

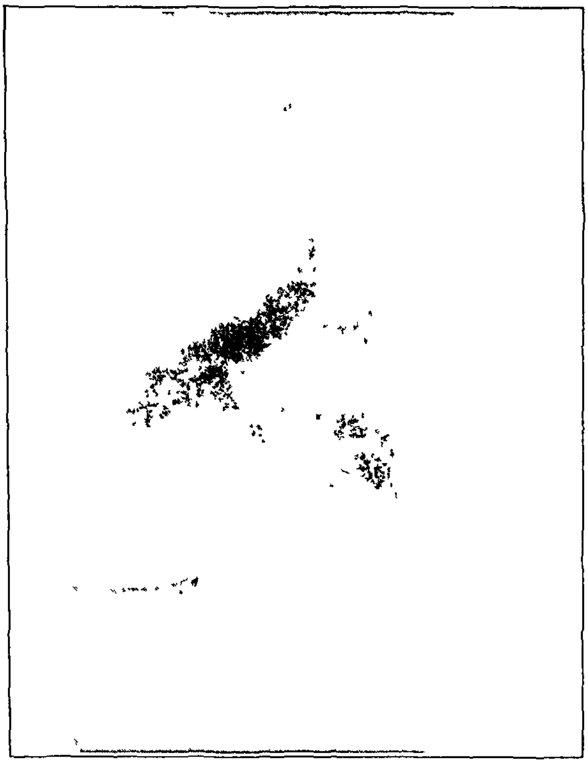

FIG. 13-A
Roentgenogram of gunshot wound of the external condyle of femur. Area of osteitis shown with surrounding sclerosis.

FIG. 13-B
Bone cavity, caused by excision of infected bone, is successfully filled with cancellous chips and covered by full-thickness skin.

of the opposite calf. A flap is designed on the calf to bridge the gap between the legs and to fit the defect. This flap is either "delayed" or, if the circulation is satisfactory, is sewed into the recipient leg, and its donor site is covered with a split-skin graft. Plaster immobilization retains the legs in position for two or three weeks, at which time the skin bridge is cut and the repair is completed.

FIG. 14
Bone defect repaired by autogenous onlay graft and cancellous bone chips.

The *abdominal tubed pedicle*: This multistage method may be used when the defect is too extensive to be repaired by other means. The pedicle is created and transferred to the leg by way of an intermediate attachment to the wrist. The main difficulty arises in the arm-to-leg position, where maintenance of an awkward posture may be necessary. Good nursing is essential.

Defect Filling by Muscle Flaps

In the deep cavities which result from infected-bone clearance in the upper tibial and lower femoral regions, it is often advisable to transpose muscle as well as skin. This minimizes the amount of cancellous bone required and provides an excellent source of blood supply.

The most suitable case is a deep medial, upper tibial defect. Here the medial head of the gastrocnemius is removed from the Achilles tendon and dissected up, leaving the branches of the medial sural artery and the nerve supply intact. When freed, this muscle is rotated over to fill the defect left after sufficient iliac bone has been packed in to ensure strength, and is sutured to the periosteum on the lateral edge of the defect. The skin cover is then sewed in over the muscle.

Similar muscle flaps can be used elsewhere, but strict attention should be paid to the conservation of the blood and nerve supply. A vascular muscle transplant is highly resistant to infection and provides a capillary bed from which the grafted bone is revascularized.

It is advisable to allow a period of at least six to eight weeks to elapse, following any extensive plastic repair of the skin and soft tissues. This permits the new blood supply to the area to become firmly established and also allows time for the reaction, consequent on any operative procedure, to subside. During this latent period every endeavor should be made to assist the recovery of the normal physiological processes in the limb as a whole.

Splinting

Splinting should be reduced to the minimum. A light plaster back splint to limit mobility at the fracture site and to prevent foot drop is all that is usually required. This can be used at night and removed during part of the day for physiotherapy.

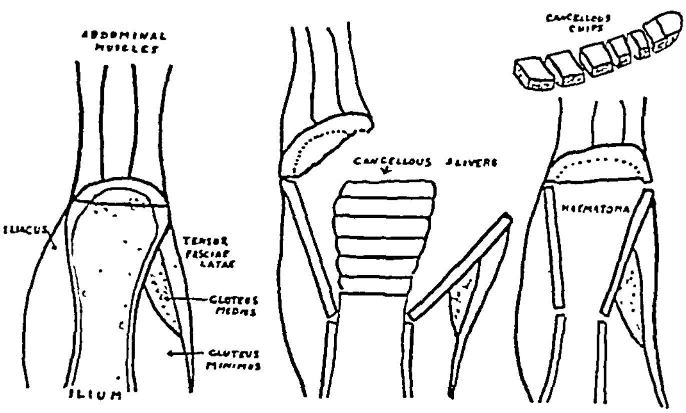

FIG. 15

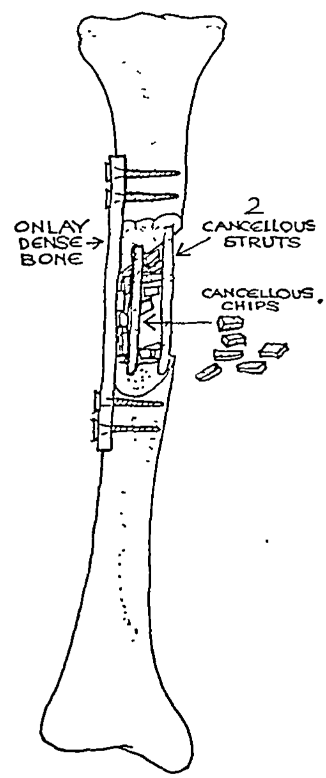

FIG. 16

Fig. 15: Diagram of operative procedure for obtaining cancellous bone from crest of ilium.

Fig. 16: Illustrating onlay graft in position and method of inserting cancellous bone. Note wide medullary exposure, into which cancellous struts are slotted and remaining defect built up with chips.

Physiotherapy

This should include mobilization of all joints, particularly those of the foot, ankle, and knee. Active exercises for the muscles of the limb, assisted if necessary by faradism, will do much to improve their tone and will improve general vascular and lymphatic supply. This preliminary treatment prior to bone-grafting is of great importance, since success in the filling of bone defects by cancellous bone chips depends largely on an adequate blood supply.

Stage 3: Bone-Grafting

Filling of Defects

As already stated, the repair of the bone defect can in certain cases be carried out at the same time as the reconstruction of the soft tissues. The bone surface is broken up with an osteotome, so that better contact can be made with the cancellous chips; and these are packed in until the cavity is filled. If a muscle flap is to be used, it should be sutured into place and the skin closure completed.

Bridging of Defects

In chronic infected compound fractures and gunshot wounds, where a substantial gap exists between the bone ends, bone-grafting has been attempted only after the two previous stages have been successfully accomplished. The method employed has been similar to that used as routine for bone-grafting fractures with non-union, the results of which have already been described by Higgs.[1] A strong autogenous cortical graft is used chiefly as a splint to maintain internal fixation, and cancellous chips have been relied upon for the production of new bone. Although the inlay graft can be used, the onlay graft (Fig. 14) has been found to give better fixation and allows the cancellous chips to be placed in direct contact with the medullary cavities, thus obtaining the maximum blood supply. If cancellous chips are simply packed in between the two bone ends there is a tendency, even when the cancellous bone shows evidence of active growth, for a line of non-union to develop between the chips and the host. For this reason it is important that strips of cancellous bone should be slotted into the upper and lower fragments (Fig. 16) so that a true bridge is formed between these two fragments. Bone chips can then be packed in between these strips until the full thickness of the defect has been made good.

Method of Obtaining Cancellous Bone

An incision is made along the anterior margin of the crest of the ilium, commencing at the anterior superior iliac spine, and extending for five or six inches. The incision is deepened, the crest of the ilium with its muscular attachments is elevated as a "lid", and the inner and outer tables of compact bone are separated and gently retracted, exposing a mass of pure cancellous bone. Strips of bone, usually 0.67 of a millimeter thick, are shaved off with an osteotome and are cut into chips about one centimeter long. Bleeding can usually be checked with hot packs. The inner and outer tables are then replaced, the "lid" sutured back into position, and the skin is closed. It is unnecessary to drain the wound, provided a firm pressure dressing is applied immediately by means of a spica bandage.

CONCLUSIONS

This complicated procedure requires the intimate cooperation of the orthopaedic surgeon and the plastic surgeon. It is an undertaking not lightly to be embarked upon, and special nursing and hospital facilities are essential for success.

It is hoped that further experience will result in simplification of the methods used, and so permit their wider application to the problems of bone sepsis.

1. Higgs, S. L.: The Use of Cancellous Chips in Bone-Grafting. J. Bone and Joint Surg., **28**: 15–18, Jan. 1946.

PYOGENIC OSTEOMYELITIS OF THE SPINE

Differential Diagnosis Through Clinical and Roentgenographic Observations

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Pyogenic osteomyelitis of the spine often presents differential diagnostic problems that are baffling. Such problems arise in cases in which the manifestations are relatively mild and some other type of spinal disease has to be considered, and those in which the presenting symptoms apparently refer not directly to the spine, but elsewhere,—as to the meninges, chest, abdomen, or hip. The intimate anatomical relation of the spinal and peripheral nerves to the infected vertebrae and the lower grades of virulence possible in many of the infecting pyogenic organisms give rise to these problems.

This study is based upon forty-eight cases of pyogenic osteomyelitis involving the vertebral body or neural arch, occurring in the cervical, thoracic, or lumbar regions, observed in the Department of Orthopaedic Surgery, State University of Iowa, from September 1934 to March 1945.*

The diagnostic problems presented by these forty-eight cases may be divided into two main groups: first, location of the lesion; and, second, determination of its nature. In the latter group, the correlation of the stage of development of the infections due to different organisms with the changes seen in the roentgenograms is of diagnostic interest.

CLINICAL SYNDROMES

I. The Hip-Joint Syndrome

Acute pain in the region of the hip joint, flexion contracture, and limitation of movement associated with pain, when accompanied by high temperature, toxaemia, and marked leukocytosis, usually lead to a tentative diagnosis of acute suppurative arthritis of the hip joint. When general and local symptoms are not so marked, the possibility of a tuberculous coxalgia arises.

In only two of our cases were the general and local symptoms of sufficient intensity to warrant consideration of the possibility of an acute suppurative arthritis of the hip joint.

When hip pain is due to a spinal condition, careful examination of the hip joint reveals three main findings that, as a rule, can be relied upon:

1. Palpation of the posterior aspect of the articulation produces no pain;
2. Trochanteric percussion usually produces pain in hip conditions, but not in spinal conditions;
3. Restriction of motion is usually confined to extension of the thigh.

Physical examination of the lumbar spine may then confirm the suspicion of a lumbar lesion by revealing the following findings:

1. Presence of a point or circumscribed area of tenderness to pressure over the affected vertebrae, associated with local muscle spasm;
2. Marked limitation of movement of the spine, particularly flexion;
3. Pain in the lumbar spine following any attempt at extension of the leg.

II. The Abdominal Syndromes

In cases in which the spinal lesion is a pyogenic osteomyelitis, high temperature, pain, sharp muscle spasm in the right lower abdominal quadrant, and slight cutaneous hyperaesthesia may be the presenting symptoms, and the laboratory studies may show marked leukocytosis and deviation of the Arneth index.

* For a general analysis of the sixty cases of this condition seen in the University of Iowa Hospitals up to September 1934, see report of Kulowski.

Carnett has called attention to intercostal neuralgia in patients complaining of abdominal symptoms, and has worked out several clinical tests which enable the examiner to differentiate between an abdominal pain due to abdominal disease and one due to an extra-abdominal lesion. These tests are based upon the fact that, if the condition is an abdominal one, local abdominal pain present during palpation diminishes or practically disappears when the patient contracts his abdominal muscles; whereas, in cases in which the cause of the local tenderness is pressure by the vertebral lesion on the roots of the nerves of the abdominal wall, no change appears.

Among our cases there was only one in which it was necessary to make a differential diagnosis between acute appendicitis and vertebral osteomyelitis.

A woman (N. R. K.—10357), whose osteomyelitic lesion involved the eleventh and twelfth thoracic vertebrae, complained several times of pain in her back, radiating down both sides of the abdomen. As a rule, these pains were not severe, but one day all the symptoms of acute appendicitis developed. The appendix was removed and the symptoms disappeared. Two weeks later, while the patient was still in the Hospital, abdominal pain again developed, and there was resistance to pressure in the right lower quadrant, accompanied by slight elevation of temperature and leukocytosis; this lasted for two days. Temperature ranging between 100 and 102 degrees continued for two weeks, during which time the patient had two similar attacks. All symptoms disappeared after the patient was placed on a Bradford frame, with traction, for one month.

III. The Meningeal Syndrome

In some cases the osteomyelitic process is characterized by an acute onset of high temperature, malaise, vomiting, headache, and clinical signs of meningeal irritation. In other cases the onset is more insidious, without elevation of temperature, but with marked generalized spinal pain and positive Kernig and Brudzinski signs. From the symptoms, an acute suppurative meningitis or a tuberculous meningitis is suspected until an analysis of the spinal fluid and the roentgenograms show an osteomyelitic focus, accompanied by a meningeal reaction.

Three of our cases presented the meningeal syndrome.

One patient (O. V. R.—38-15274), a boy of eleven years, showed all the symptoms of acute infectious meningitis. Several days before his admission to the Hospital another patient from the same town had been admitted to another service with similar symptoms. Epidemic meningitis and tuberculosis were ruled out on the basis of negative findings in the spinal fluid—including smears, cultures, and guinea-pig inoculation—the evolution of the process, negative tuberculin and agglutination tests, and the appearance, two weeks after onset, of a destructive process localized in the inferior epiphyseal region of the ninth thoracic vertebra, accompanied by a narrowing of the corresponding intervertebral disc. The clinical symptoms disappeared two weeks after onset. The patient has been followed for eight years; the only abnormality present is a diminution of the intervertebral space between the ninth and tenth thoracic vertebrae, with what appears to be a calcification of the nucleus pulposus.

The other two patients presented similar symptoms, except that in both cases the temperature rise and systemic reaction were minimal. One was ten and the other twenty years old. In both patients the tuberculin tests, smears, guinea-pig inoculation, and agglutination tests were negative. The roentgenograms became positive between three and four weeks after the onset of symptoms, and showed localized lesions at the level of the epiphyseal regions, with coincident narrowing of the intervertebral disc.

IV. The Back-Pain Syndrome

At the time of admission to the Hospital, forty-two of our patients complained of pain in the back. According to the onset and the intensity of clinical symptoms, they may be placed in one of the three classical groups: acute, subacute, and insidious. The peculiar differential diagnostic problems of each group may be stated as follows:

A. Acute Form (Sixteen Cases)

In this group, the average age was thirty-five years. The oldest patient was sixty-two, and the youngest was eighteen.

There was a sudden onset of back pain,—severe, constant, and, in the majority of cases, increasing in intensity and interfering with sleep; in some there was radiation of pain to the corresponding peripheral segments (chest, abdomen, or extremities). Local tenderness and muscle spasm were marked. All patients were toxic. Temperature elevation, high in all, had been present since onset of the disease in twelve patients; in three patients it appeared after two days, and in one after a week.

Leukocytosis was present, with white blood cells ranging from 12,000 to 35,000. The sedimentation rate was increased. Agglutination tests for Malta fever, typhoid, and paratyphoid fever were negative in all cases, as was the Wassermann reaction.

The blood culture was positive for non-hemolytic *Streptococcus* in one case, and positive for *Staphylococcus aureus* in six cases. It was positive for *Streptococcus viridans* in two cases and negative for this organism in two cases. In the remaining cases the record is not available, since these patients were not seen on this Service until after the acute stage.

Abscess formation appeared in twelve patients after intervals of from one to three weeks following the onset of the clinical symptoms. The diagnosis in these twelve cases was confirmed later, when smear, culture, and guinea-pig inoculation had ruled out all except the pyogenic micro-organisms. In ten of the cases with abscess, hemolytic *Staphylococcus aureus* was obtained; in one there was beta-hemolytic streptococcus; in another—with sinus formation on admission—both *Streptococcus viridans* and *Staphylococcus albus* were obtained.

In the remaining cases, without abscess formation, the diagnosis was based on the typical clinical course and the sequence of roentgenograms. Other peculiarities in favor of the diagnosis were as follows:

In one case the destructive process in the spine appeared three weeks after onset of a pyogenic infection of the patient's hand. On admission the blood cultures were positive for non-hemolytic streptococcus. All other tests were negative, except the tuberculin test. The vertebral lesion healed, and in seven months produced a solid block of two vertebral bodies. The patient has been completely free of symptoms for the past nine years.

In another patient, the vertebral lesion started three weeks after the healing of a suppurative mastoiditis, which had been draining for the previous two months. Tests for other conditions were negative. The spinal lesion healed in six months. The patient has been completely free of symptoms for the past seven and a half years.

Two other patients were admitted four weeks after the onset of the process. The history was typical of pyogenic spondylitis, and no other source of infection could be detected. According to the roentgenograms, the spinal lesion healed in from seven to eleven months; the observation time of complete cure has been five and nine years, respectively.

B. Subacute Osteomyelitis of the Spine (*Seven Cases*)

In these patients the toxaemia is mild. In three of these seven, the process started following serious pyogenic infections in other parts of the body (lesion of the upper lip, perinephritic abscess, pyogenic tenosynovitis). In all of these patients the tuberculin test was negative, as were all other skin and agglutination tests.

In another patient (M. F.—38-15120) the onset was insidious, with low temperature, backache of mild character, and formation of several abscesses, which clinically showed the characteristics of a cold abscess. Roentgenograms of the spine showed destruction accompanied by marked decalcification, and so the possibility of a tuberculous spondylitis was seriously considered. For these reasons, four guinea pigs were inoculated with the pus; all tests were negative. The agglutination tests and the fungus cultures were also negative. The only bacteria that could consistently be obtained from the pus were the beta-hemolytic streptococcus and the *Staphylococcus aureus*. One year later, the patient died, after progression of the infectious process, and the postmortem findings confirmed the diagnosis.

The remaining three cases constitute a subgroup that present special clinical and diagnostic problems,—the group with epidural abscesses. Cohen and Dandy have both written about the diagnosis of epidural abscess.

Infection of the epidural space occurred in our cases as a complication of osteomyelitis of the laminae. The diagnosis was made clinically in two of the cases. In one of these, a flaccid paralysis of the lower extremities developed, following elevated temperature, pain in the low back, and difficulty in voiding.

The other patient had a furuncle on his left forearm, and one month later the same clinical picture, characterized by back pain, slight temperature elevation, and difficulty in voiding, appeared. Two days later signs of meningeal irritation became evident. On admission, an emergency drainage of the back was performed. The patient died one month later. At necropsy, acute osteomyelitis of the laminae was found, with several abscesses in the epidural space from the thoracic to the lumbar region, in addition to multiple pyogenic foci in the pleura and kidneys. The culture showed hemolytic *Staphylococcus aureus*.

The following case presents the typical history, and constitutes a good example of the differential diagnosis between an epidural abscess and any other condition producing low-back pain.

Two weeks before admission the patient, while lifting a heavy load, felt a sudden, sharp pain in his low back. The pain became progressively worse, and during the following days it could not be controlled by strapping, traction, or morphine. Ten days later, difficulty in voiding developed, requiring catheterization. Physical examination on admission revealed tenderness over the spinous process of the third lumbar vertebra, marked limitation of motion of the lumbar spine, and marked muscle spasm. The patient was unable to stand, because of weakness in the lower extremities and tremor in his right foot. Neurological examination was otherwise essentially negative. For ten days the patient was kept in traction, but the pain became so severe that syncope occurred on one occasion. The daily temperature was 100 degrees, which was the same as that recorded on admission. There was slight leukocytosis; the roentgenograms were negative. During the next week the patient improved slightly; therefore conservative measures were continued. One and one-half months after the onset of the initial symptoms, the patient had a severe pain in his back with radiation down both legs. No relief was obtained by the use of morphine, and a laminectomy was performed. A typical epidural abscess was found at the level of the fourth lumbar interspace, secondary to an osteomyelitic process of the neural arch.

As far as the differential diagnosis between an epidural abscess and a chronic granuloma is concerned, our experience is based upon only one case of chronic granuloma, appearing in a patient with infectious spondylitis produced by Malta fever. In the granuloma the development of the process was slower, over a period of eight months, and the pain was not so severe.

Epidural abscess may be differentiated from neoplasm developing in the spine by the presence of temperature elevation and leukocytosis, and by the sudden onset and rapid development of the process. The growth of a neoplasm usually continues for a period of months instead of days.

C. Osteomyelitis of the Spine of Insidious Onset (*Nineteen Cases*)

These patients did not experience temperature elevation or other general reaction. In most cases the pain was very sharp and was not relieved by rest; it was more intense at night and was aggravated by coughing and sneezing. Radiation of pain was not a constant feature. Loss of weight was present in practically all of the cases.

The most constant physical findings were limitation of motion of the spine and the detection, either by palpation or percussion, of an area of localized tenderness. Roentgenograms showed the presence of a destructive process in the vertebral bodies of seventeen of the cases. In the other two cases, the destruction was limited to the neural arches.

In view of such a clinical and roentgenographic picture, other infectious processes should be taken into consideration. Typhoid and paratyphoid fever, Malta fever, mumps, and pneumococcus spondylitis can usually be ruled out by the clinical history, the agglutination test, and the skin test. However, the question: "Is this process a low-grade pyogenic or a tuberculous osteomyelitis?" arises almost daily.

In considering this question, we must separate the cases in which the infectious

process is localized exclusively in the neural arches, because these cases are practically always of pyogenic origin. Invasion of the posterior arches by the tubercle bacillus is uncommon. Anderson stated that up to 1940 there were only twelve cases of tuberculosis of the spinous process cited in the foreign literature; he reported the first case in the American literature.

Our two cases of insidious onset and course, with isolated destruction of the neural arches, were both proved to be osteomyelitis. Pus collected, with all the clinical symptoms of a cold abscess, several months following the onset of symptoms, and the cultures yielded *Staphylococcus aureus*.

Of the remaining seventeen cases of pyogenic spondylitis of insidious onset and evolution, affecting the vertebral bodies, the differentiation between pyogenic infection and tuberculosis was based on the following findings:

1. In four cases, pyogenic organisms were cultured from the pus of abscesses, with the clinical characteristics of cold abscesses, that appeared several months after the onset of symptoms.

2. In three cases, the destructive spinal condition appeared from two to three months after an intense pyogenic infection in some other part of the body.

3. In two cases, the patients had several active foci of osteomyelitis involving the extremities.

4. In five cases, the tuberculin test was consistently negative, in spite of being repeated several times at different concentrations.

5. In the remaining three cases, our diagnosis was justified by the following means: (a) Other infectious processes were carefully ruled out and (b) the series of roentgenograms showed a process identical in its course with that of proved cases of pyogenic osteomyelitis of the vertebral bodies.

With two exceptions, all the cases of this group have been observed for more than five years, during which time the patients have been completely free of symptoms and there has been no reason to change the diagnosis.

DIFFERENTIAL DIAGNOSIS OF PYOGENIC SPONDYLITIS FROM A ROENTGENOGRAPHIC POINT OF VIEW

In pyogenic infections affecting the neural arch, we have found involvement of the spinous articular and transverse processes, and of the laminae. The infections that involve the vertebral body may be either localized or diffuse. Each of these two possibilities presents different diagnostic problems.

Unfortunately there are no reliably characteristic roentgenographic findings for the different types of infectious spondylitis. As regards the diagnosis of spondylitis due to Malta fever, typhoid fever, mumps, or any other specific vertebral infection, it is necessary to rely mainly on the clinical history, the agglutination tests, the skin tests, and the blood findings in each case. In our cases we found that, after all the possibilities had been exhausted, the most frequent diagnostic problem was to differentiate between pyogenic and tuberculous spondylitis.

For the reasons just explained, forty-three cases of proved tuberculosis of the spine, with good roentgenographic follow-up and presenting initial lesions very similar to those encountered in the cases of pyogenic spondylitis, have been selected for comparison in this study.

Pyogenic Osteomyelitis Affecting the Vertebral Body

A. Localized Forms

In the localized forms of pyogenic infection of the vertebral body, the lesion was a small, circumscribed destructive area, situated close to the epiphyseal ring or the cartilaginous plate. A slight narrowing of the intervertebral disc was present in the first stages

of the process, accompanied by some atrophy of the bony tissue surrounding the focus of infection. Within an average of from four to six months some sclerosis appeared around the initial focus, and in some cases a slight reactive new-bone formation was visible as early as three months following the onset of symptoms. In our cases, the process healed within periods ranging from nine to twelve months. The roentgenographic follow-up of these patients for periods exceeding five years showed that the only residual abnormalities were irregularities in outline of the previously affected body, a thinning of the intervertebral disc, and, in some cases, a localized osteophytic formation.

FIG. 1

Roentgenogram showing notching of the inferior surface of the body of the third lumbar vertebra and of the upper surface of the body of the fourth lumbar vertebra. There was slight diminution of the intervertebral space.

There were eight cases of localized pyogenic spondylitis in our series. In two patients, the destructive process was initially located at approximately the center of the upper or lower surface of the vertebral body. One of these healed in six *months, the only residual alterations being* a thinning of the intervertebral disc and what appeared to be calcification of the nucleus pulposus that has been persistent for the last six years of observation. The

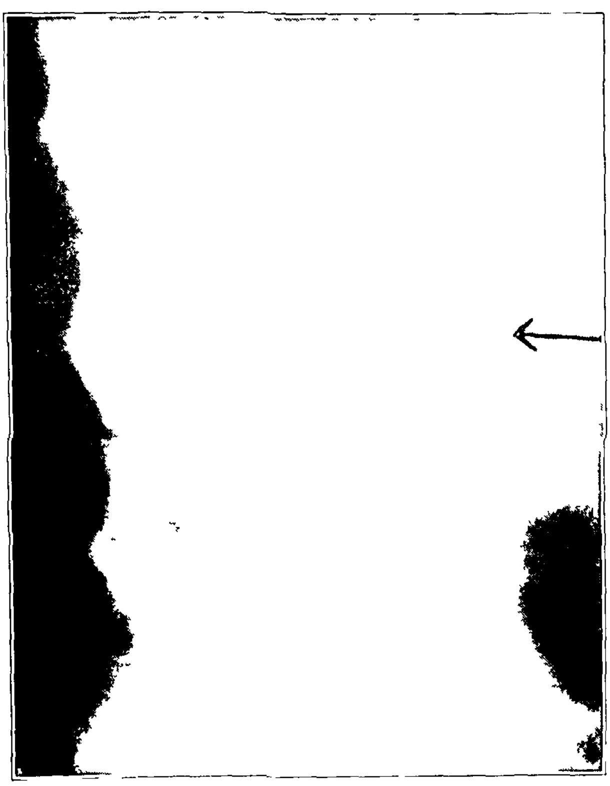

FIG. 2

Localized lesion in upper anterior border of the body of the third lumbar vertebra, two weeks after the onset of the clinical symptoms.

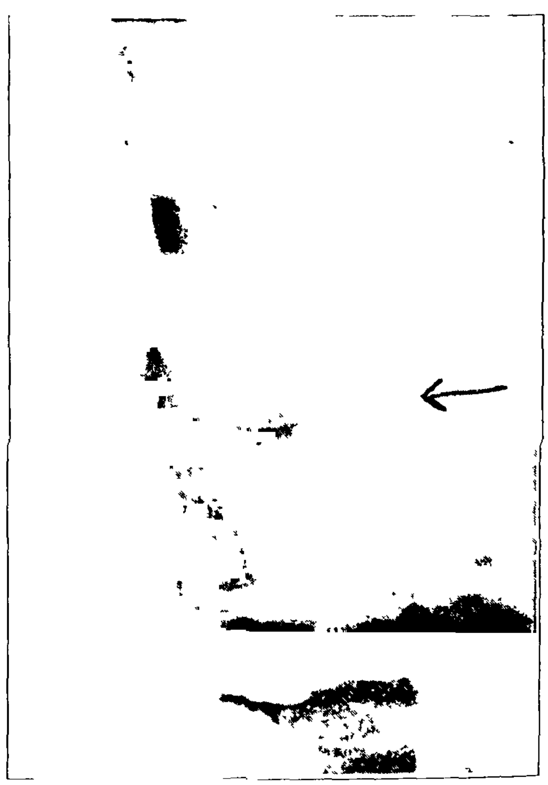

FIG. 3

Localized lesion in another case of proved osteomyelitis of the spine, five months after onset of the clinical symptoms.

other patient had a similar localization and evolution, the residual deformities being a notching of the upper and lower surfaces of the two contiguous vertebral bodies and a diminution of the intervertebral space (Fig. 1).

Ghormley, Bickel, and Dickson reported several similar cases and explained the etiology as infectious processes confined to the intervertebral disc. The fact that our two patients were boys ten and eleven years old, respectively, could be used as evidence in favor of this hypothesis.[20] It is difficult, however, to determine whether the notching of the vertebral surfaces in our second case was due to a primary osseous focus or was only a deformity secondary to an infectious process of the intervertebral disc.

In four cases the localized pyogenic focus was situated in the epiphyseal ring (Figs. 2 and 3). The patients were between two and fifteen years of age. In one of them we were able to recognize signs of new-bone formation one month after the onset of the clinical symptoms (Fig. 4). Gottlieb reported a similar case and explained the cause as an infectious process circumscribed at the annulus fibrosus. Freedman described a proved case in a fourteen-year-old girl, in which only the epiphyseal ring was involved. We have not observed any cases of the localized type in adults.

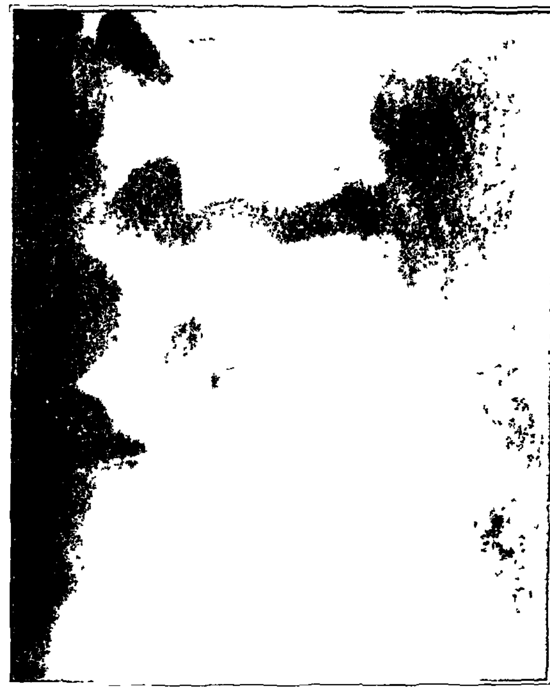

FIG 4

Localized destructive lesion of the lower surface of the third lumbar vertebral body, four weeks after onset of the clinical symptoms There is a decrease of the intervertebral space and reactive new-bone formation.

Another group of localized pyogenic infections was represented by two cases in which the process affected exclusively either the anterior or the lateral surface of one or several vertebral bodies. This was observed in patients with osteomyelitic involvement of the neural arches; when surgical drainage was performed, several abscess extensions were found directed toward the vertebral bodies. Such extensions were also found in an abscess spreading along the anterior surfaces of the contiguous vertebrae.

If these different types of lesions are considered from the point of view of the differential diagnosis, it will be observed that any one of them can be produced either by a pyogenic or by a tuberculous organism. It is not the shape of the lesion or its localization that makes it possible to differentiate between the two conditions. Only through careful study of roentgenograms taken at intervals over a considerable period of time will the differences in the progress of the two lesions make possible a differential diagnosis.

Fifteen cases of proved tuberculous epiphyseal spondylitis were studied for purposes of comparison. Similar to our pyogenic cases, during the early stages of the process they presented a progressive thinning of the intervertebral space, atrophy of the osseous tissue, decalcification, and, in some, a focus situated just below the epiphyseal plate. However, the evolution or progress of the two diseases was different. In the cases of osteomyelitis, the process lasted from nine to twelve months; in the tuberculous cases, the thinning of the disc progressed for periods averaging two to three years. In the pyogenic cases, diminution of the intervertebral space was only partial; in the tuberculous cases (due to longer duration of the process), the thinning progressed slowly, until both vertebral bodies came

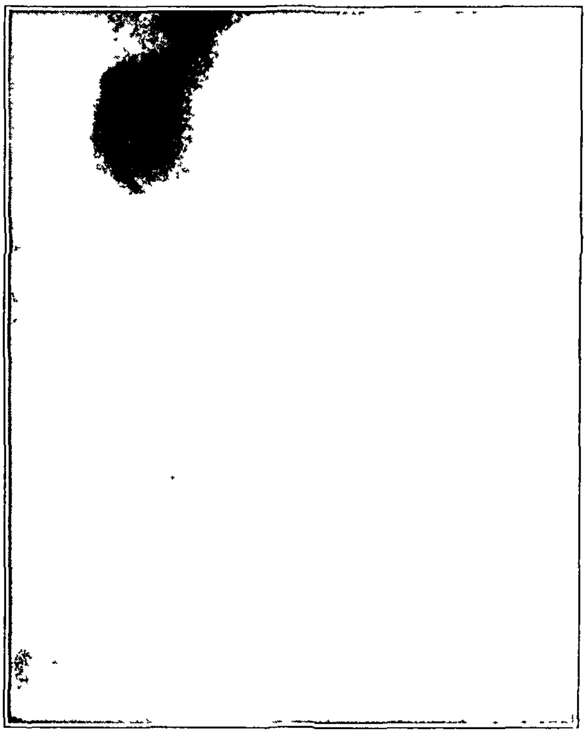

Fig. 5

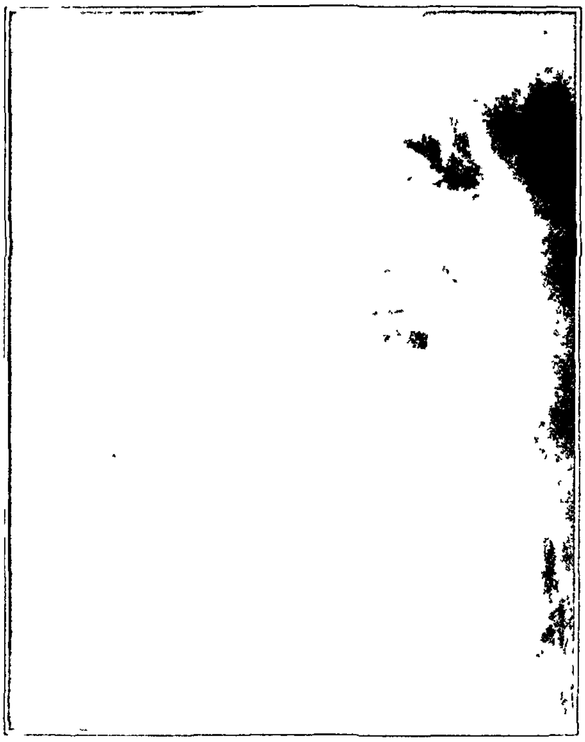

Fig. 6

Fig. 5: Epiphyseal type of proved tuberculosis three years after onset of a slow and progressive thinning of the intervertebral disc.

Fig. 6: Marked bone-bridging in a proved case of osteomyelitis of the spinous processes, laminae, transverse processes, and lateral surfaces of the vertebrae, due to *Streptococcus haemolyticus*. The bridging extends from the first to the fifth lumbar vertebra, the intervertebral spaces being preserved.

in close contact (Fig. 5). In pyogenic cases, reactive new-bone formation could be recognized as early as one to three months after the onset of symptoms; spur formation in the tuberculous type was minimal, late, or not present at all. Finally, the sclerosis around the primary focus was clearly visible early in the cases of pyogenic infection; in tuberculosis it was absent or of very mild intensity in the early stages.

The differential diagnosis in cases involving the anterior or lateral surface of the vertebral body depends upon the roentgenograms. In some cases of tuberculosis, there was a notching of the anterior surfaces with preservation of the intervertebral disc and cartilaginous plates; while in pyogenic infections, although the intervertebral spaces were preserved, the process had produced several spicules of new bone, easily detectable in the lateral view, or marked bone-bridging (Fig. 6).

B. Diffuse Forms

In these cases the process is not localized, but produces a diffuse pyogenic spondylitis. This occurred in thirty-two of our cases of pyogenic spondylitis. For differential purposes, we have compared them with twenty-eight cases of the central type of tuberculous spondylitis, of which good follow-up roentgenograms were available.

In pyogenic infections of the vertebral bodies, during the early and atrophic stages, a fuzziness of the limits of the upper and lower surfaces of the vertebral bodies could be observed, as well as a lessening in their density (Fig. 7-A). However, this isolated atrophy did not last long. As early as two months after the onset of symptoms, small spicules of reactive new-bone formation were observed. Eventually the atrophy was replaced by a dense sclerosis, present throughout the entire remaining portions of the bodies of the two contiguous vertebrae (Fig. 8-A). This sclerosis appeared as early as three months after the onset of symptoms, and persisted for periods ranging from three to six months. A solid bony block appeared at the termination of the period of sclerosis (Fig. 8-B). In one case,

FIG. 7-A
One and a half months after the onset of symptoms, the entire intervertebral space was involved.

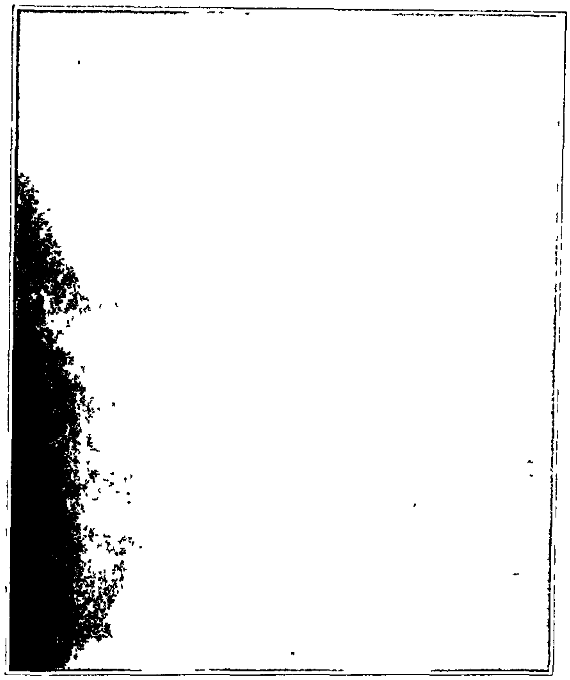

FIG. 7-B
Four months after onset of symptoms

with progressive spreading of the process, the atrophy persisted until the death of the patient, one year later.

On the other hand, the cases of infectious spondylitis, produced by the tubercle bacillus, presented marked atrophy for at least two years. This atrophy was rarely replaced by sclerosis, but usually by a clearer delineation of the structure and trabeculation of the vertebral bodies. Increase in density, in our recumbent tuberculous patients, was a transitory and mild phenomenon, except when it was due to the presence of sequestra or sudden collapse of the body, or when it occurred in cases with mixed infections. Block formation was a very late phenomenon, usually between four and six years after the onset of the clinical symptoms, and was prone to produce sudden collapse of the diseased vertebrae.

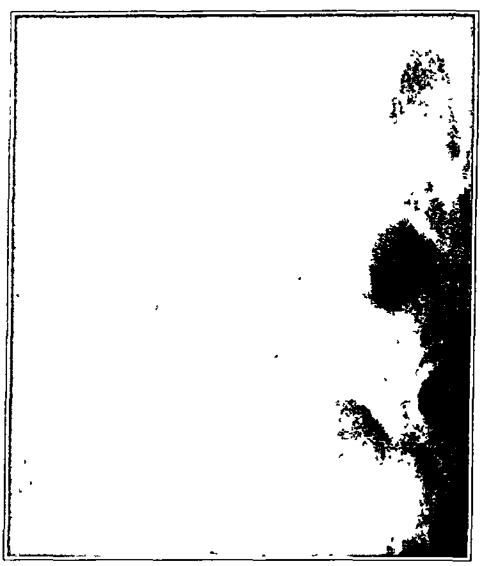

FIG. 7-C
One year after onset of symptoms.

Reactive new-bone formation, which was a rare phenomenon in the tuberculous cases, except in those of long duration, was seen in the lower segments of the lumbar spine, where calcification or ossification of the intervertebral ligaments was also evident.

Although there is no doubt that marked reactive bone formation does occur in certain cases of tuberculosis of the spine, it is rare. When it does occur, it is usually in the late stages of the process and is usually circumscribed at the lumbar spine. On the other hand, in the diffuse forms of pyogenic spondylitis, reactive new-bone formation is, as a rule, an early and marked phenomenon.

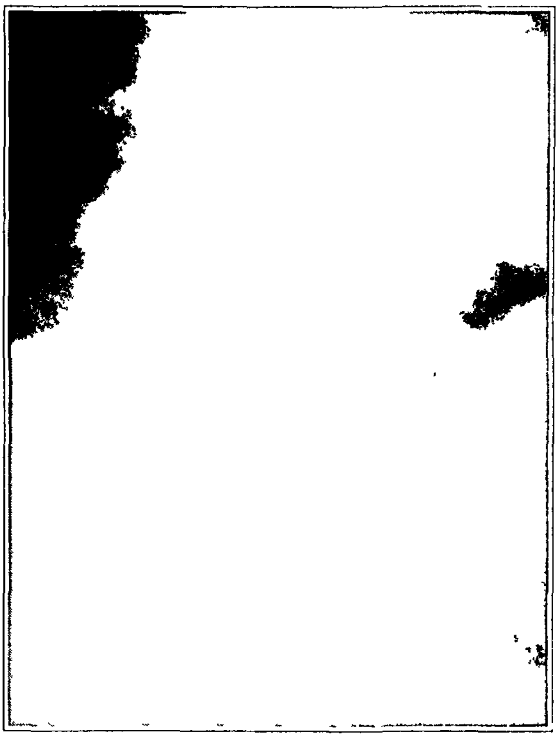

FIG. 8-A

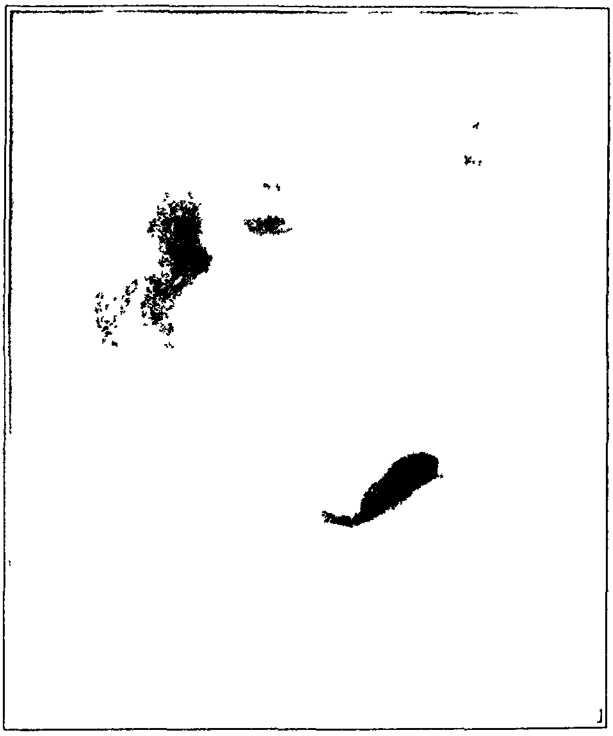

FIG. 8-B

Fig. 8-A: Complete involvement of the intervertebral space between the ninth and tenth thoracic vertebral bodies, seven months after the onset of symptoms. There is marked sclerosis of the involved vertebral bodies.

Fig. 8-B: Solid block one year after onset of symptoms.

Increased Roentgenographic Density in Cases of Tuberculous Spondylitis

It is erroneous to assume that areas of increased roentgenographic density cannot b observed in cases of tuberculous spondylitis. Aubry and Pitzen have called attention t the fact that in some cases there is an increase of the osseous density at the level of th pathological process, and they attributed this phenomenon to a process of trabecula penetration secondary to pressure. Later, Freund confirmed these findings in cases o tuberculous spondylitis with caseation, and explained them on the basis of the affinit that the caseous material has for the calcium salts.

Finder described the presence of sclerosis and sequestration in a case of healin tuberculosis of the spine, and believed that these conditions were due to the healing process Compere and Garrison were able to confirm these findings only in cases of secondaril infected tuberculous spondylitis, and attributed Finder's observations to the fact that hi specimen was obtained from a patient who had multiple abscesses and discharging sinuses

More recently, Cleveland and Bosworth have called attention to the fact that ther is a high incidence of sclerosis in human tuberculosis of the spine, due to a massive los of blood supply. Auerbach and Stemmerman also found that, in the roentgenograms o hemisections of spines with productive tuberculous lesions, there were consistently present areas of increased density that, for lack of a better term, were referred to as areas o sclerosis.

In spite of all these descriptions, the fact remains that in tuberculosis of adults, areas of increased density are not frequently found in the roentgenograms of living subjects, with the exception of patients with secondary infection, huge sequestra, or sudden collapse. Areas of increased density are sometimes observed in children during the very early stages of the disease, or during the healing period.

This apparent paradox can be explained by the statement of Cleveland and Bosworth that, in most cases, the roentgenographic images fail to reveal the presence or full extent

of the condition. Although the roentgenograms of their pathological specimens showed either mottling or very definite sclerosis, the roentgenograms of the same patients, taken during life, showed definite sclerosis in only one case (Sea View Hospital, No. 11322). In another case (Sea View Hospital, No. 2797) the amount of sclerosis and calcification seen by roentgenogram, taken before death, was so slight that it escaped the notice of the authors.

The same discrepancy between the roentgenograms of living subjects and those of pathological specimens was emphasized by Bosworth in 1939. More recently, Auerbach and Stemmerman have reached similar conclusions.

Therefore, although increase of density and sclerosis in tuberculous spondylitis, as seen in the roentgenogram, is a phenomenon which it is difficult to observe in living subjects, in pyogenic spondylitis it is clearly visible, accompanied by spur formation and appearing after an atrophic period lasting from a few weeks to a few months. Consequently, it has great diagnostic value in differentiating between the two conditions.

As previously stated by Steindler, the cases of so-called tuberculous spondylitis, characterized in the roentgenogram by marked sclerosis and bone formation, should be observed with suspicion, as they may prove to be cases of chronic staphylococcic osteomyelitis.

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OSTEOCHONDROMATA OF THE PELVIC BONES

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While the generally accepted opinion is that osteomata and osteochondromata are benign lesions, it is recognized by those who have seen many of these lesions that they may sometimes be difficult to eradicate surgically, and at times may apparently become malignant and terminate fatally. This is particularly true of lesions involving the bones of the pelvis. When such a tumor has a definite pedicle, and complete surgical removal can be carried out, the prognosis is good. On the other hand, many of these tumors, particularly those arising in cancellous bone, are not well pedunculated, and complete surgical removal is difficult. The extent of involvement of cancellous bone by chondromatous tissue is often difficult to determine, because the roentgenogram does not reveal its extent, and about the only way to determine the presence of chondromatous tissue is by examination of microscopic section. Lesions on the inner surface of the pelvic bones may be almost completely inaccessible by any type of conservative surgical procedure.

The symptoms which cause the patient to seek relief are pain, swelling, and deformity. In some instances, however, no symptoms are present and the lesion is discovered accidentally when roentgenograms are made for some other reason. Pain may have persisted for several years before the true nature of the condition is discovered. In some cases, in which for various reasons surgical removal has not been accomplished, the tumors have grown to huge size, and the patient has suffered intense pain for many years.

Meyerding [1] has reported the removal of 265 exostoses from 232 patients. The known duration of the condition varied from a few days to thirty-five years; the average duration was four and one-half years. Eighty per cent. of the patients were between the ages of eleven and forty years. In 39 per cent. there was a history of trauma, although in many cases the injury caused recognition of a pre-existing condition. Four of the patients stated that the condition was familial. Of the pelvic lesions, fourteen were situated in the ilium, four in the pubis, and two in the ischium. In 10 per cent. of the cases, the osteochondromata recurred after they had been removed surgically.

MATERIAL

The present paper is based on a study of forty patients with osteochondroma of the innominate bone, upon whom operation was performed at the Mayo Clinic during the years 1910 to 1943, inclusive. In each case the diagnosis was verified by microscopic examination. Twenty-six of the patients were males, and fourteen were females. Their ages ranged from four to sixty-two years; the average age was thirty-three and one-half years. Three of the patients had multiple congenital exostoses.

CLINICAL DATA

In thirty-seven patients, the duration of symptoms varied from one week to twenty-one years, averaging three and one-half years. In the other three, the tumor was discovered incidentally. The initial symptoms were as follows: A mass was discovered in seventeen patients, pain in thirteen, a limp in one, a weak leg in one, urethral discharge in one, a slow urinary stream in one, a limp and "tired" hip following injury in one, and a limp and an ache following "poliomyelitis" in childhood in one. The original symptom was not recorded in one case.

In six patients, trauma had preceded the onset of symptoms. The interval between the injury and the onset of symptoms varied from one to sixteen years; the average interval was four and one-half years. Three other patients said that an injury had occurred at the time the symptoms had begun.

At some time during the course of the disease, twenty-eight patients had experienced pain or discomfort; this was described as tenderness to pressure, an ache, or a severe pain. Two patients complained of pain which did not seem to be related to the tumor. Twenty-one patients had noted a mass or a prominence. In one case the tumor had been discovered by the family physician. In two cases the tumors were found during childbirth, and in two cases they had been discovered by roentgenographic examination. Fifteen patients stated that the mass had increased in size. A limp was recorded in seven cases. One patient (Figs. 1-A and 1-B) complained of a urethral discharge, and another (Figs. 2-A and 2-B) complained of both a slow urinary stream and a progressive decrease in the size of his stools.

The location of the tumors is shown in Table I. The primary lesion was intrapelvic in ten cases; in five cases, the recurrent lesions were intrapelvic. The right side was involved in sixteen cases, and the left in twenty-four cases.

TABLE I

SITE OF INVOLVEMENT

	Number of Cases
Ilium	
Anterior superior spine	10
Crest and wing	7
Posterior spines	4
Acetabular region	3
Too large to localize	4
Pubis	8
Pubis and ischium	3
Ischium at acetabulum	1
Acetabulum and femur	1
Total	41*

* One patient, who had multiple congenital exostoses with lesions of ilium and pubis, is included twice.

In twenty-six cases, roentgenographic examination did not disclose evidence of metastatic involvement of the thorax, and in one case the presence of such involvement was questionable. In the remaining thirteen cases, no mention was made of metastatic involvement of the thorax.

TREATMENT AND RESULTS

Sixty-nine surgical procedures were carried out on the forty patients (Table II). In one patient, twelve operations, in addition to cauterization, were performed in twenty-three years. Eleven attempts were made to excise the tumor, and on another occasion a sinus was curetted. Five operations were performed on one patient; three operations were performed on three patients; two operations were performed on four patients; and one operation was performed on twenty-eight patients. In two cases, excision was performed in two stages. In eight cases, cauterization was applied after the first procedure. In five of these cases, the tumor had not recurred when the patients last were heard from. The tumor had recurred in two cases, and follow-up data could not be obtained in the remaining case.

Table III shows the diagnoses based on microscopic examination. In the first case listed, the patient apparently was well eight years after the last operation. In the second case, the patient died five months after the last operation. When follow-up data last were obtained in the third case, the condition of the patient was becoming worse. The fourth patient died thirteen months after the last operation. The fifth patient died of a recurrence, four years after the last operation. The sixth patient underwent another operation after he left the Clinic. In the seventh case, a recurrent tumor was removed ten months after the first operation. When follow-up data last were obtained in the eighth case, the condition

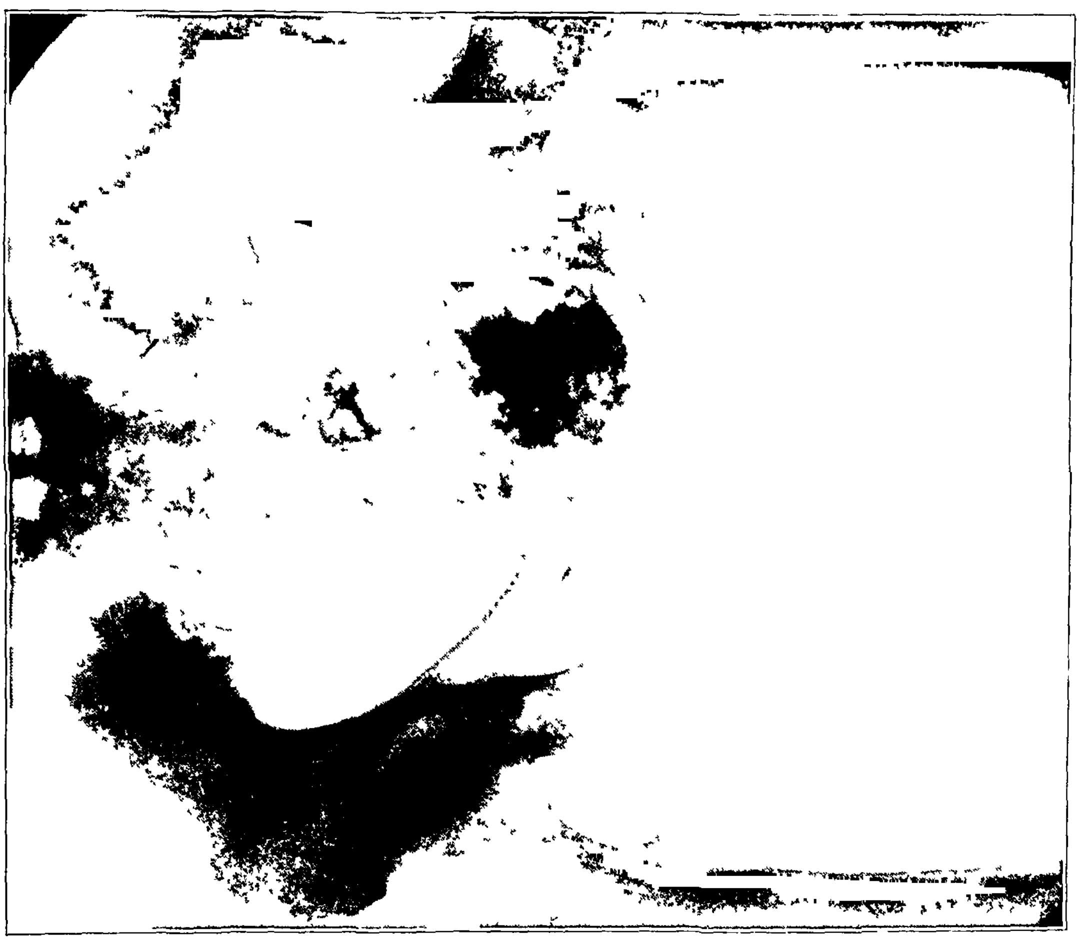

Fig. 1-A

Roentgenogram showing osteochondroma which had caused a urethral discharge.

Fig. 1-B

One month after removal of the tumor.

Fig. 2-A

Roentgenogram showing osteochondroma that had caused slowing of the urinary stream and a decrease in the size of the stools.

Fig. 2-B

Recurrence of tumor eleven months after operation.

TABLE II

SURGICAL PROCEDURES CARRIED OUT ON PATIENTS WITH OSTEOCHONDROMATA

Procedure	Times Procedure was Performed in Respective Cases	Number of Cases	Number of Procedures Performed in Respective Cases
Excision Cauterization	12 1	1	13
Excision	5	1	5
Excision	3	3	9
Excision	2	4	8
Excision in stages	2	2	4
Excision Partial excision	1 1	1	2
Excision	1	22	22
Partial excision	1	4	4
Biopsy	1	2	2
Total		40	69

of the patient had become worse. In the ninth case (Figs. 3-A, 3-B, and 3-C) the tumor had not recurred ten months after the last operation. The weight of the tumor, which was recorded in twenty instances, was between 20 grams and 2,850 grams.

Some observers believe that, once incompletely removed, many, if not all, of these tumors tend to become more active in their growth and ultimately to become malignant. We cannot prove this to be consistently true from the facts revealed in this review. In the first case in Table III, the condition was twice diagnosed as sarcoma on microscopic examination, but nine times as a benign lesion. The fact that the patient was well eight years after the last operation would leave doubt about the presence of a malignant lesion.

Eleven patients received postoperative irradiation therapy. In seven of these cases, roentgenotherapy was employed; in two, radium therapy was employed; and in two, both radium and roentgenotherapy were used.

TABLE III

DIAGNOSES BASED ON EXAMINATION OF PATHOLOGICAL SPECIMENS

Diagnosis	Number of Times Diagnosis was Made in Respective Cases	Number of Cases
Chondrosarcoma Inflammation Osteochondroma	2 2 7	1
Osteochondroma Mixed-cell sarcoma	1 1	1
Osteochondroma	5	1
Osteochondroma Chondromyxosarcoma	2 1	1
Myxochondroma Osteomyxochondroma	1 1	1
Osteochondroma	3	1
Osteochondroma	2	1
Cellular chondroma or malignant osteochondroma	1	1
Chondroma Recurrent cellular chondroma	1 1	1
Osteochondroma	1	20
Chondroma	1	6
Degenerating osteochondroma	1	3
Degenerating chondroma	1	1
Myxochondroma	1	1
Total		40

In two of the seven patients receiving roentgenotherapy, the only surgical procedure prior to this treatment was the removal of tissue for biopsy. One of these patients has died, and the other underwent a subsequent operation. In the third case, the tumor was partially removed; two courses of postoperative roentgenotherapy were given at the Clinic, and two courses were given elsewhere. The patient was reasonably comfortable when last heard from, thirty-three months later. In the fourth case, we gave a second course of postoperative roentgenotherapy after it had been employed elsewhere, but the patient died. In two other cases in which postoperative roentgenotherapy was employed, the patients also have died; in one, roentgenotherapy was

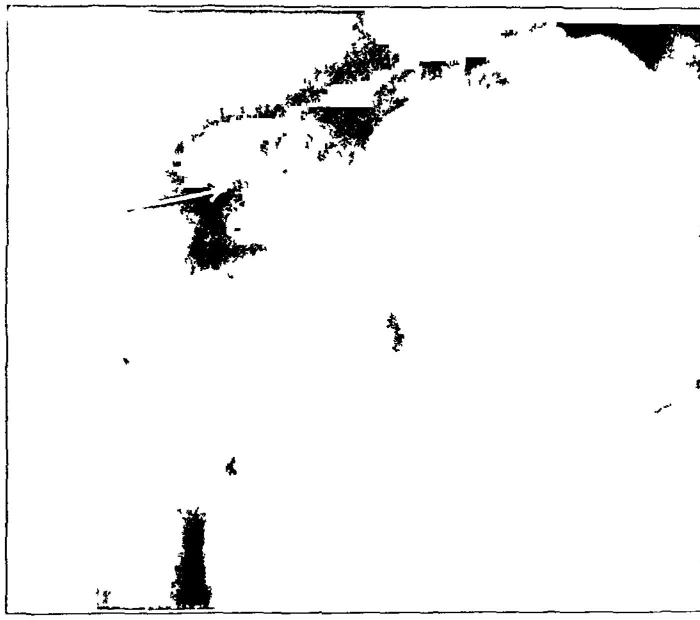

Fig 3-A
Chondroma of right ilium

Fig 3-B
Outer surface of innominate bone
(Arrow indicates chondroma)

Fig. 3-C
Inner surface of innominate bone
(Arrow indicates chondroma)

employed after three unsuccessful attempts to remove a lesion that proved to be malignant. In the seventh case, the patient was well ten years after discharge from the Clinic.

In one case in which radium therapy was employed, the patient has died. In the other case, radium therapy was employed after the removal of a recurrent tumor. When the patient returned to the Clinic on two occasions during the next year, there was evidence that the tumor had recurred; however, eleven years later the patient was well, and stated that he had not observed any evidence of recurrence of the tumor.

In one of the two cases in which both types of irradiation treatment were employed, the tumor recurred; in the other case, the patient has died.

The value of roentgenotherapy or radium therapy in these cases seems doubtful. There was only one case in which it may have done any real good.

One patient, who has undergone three operations since leaving the Clinic, subsequently returned with metastatic involvement of the thorax. Another patient has had two operations since he left the Clinic. Two patients were given irradiation therapy elsewhere after they had been operated upon.

Nine, or 22.5 per cent., of the forty patients are known to have died. Their symptoms had been present for from nine months to twenty-one years before the patients first were operated upon at the Clinic; the average duration was five and one-half years. In seven of these cases, the patients lived for from one to six years after they were operated upon; the average period of survival was 3.3 years. The date of death of one of the two remaining patients is unknown; the other died of operative shock.

It must be noted that we do not have necropsy findings to determine the true nature of the lesions. If such findings were available, they might show malignant changes in several of these patients.

Eight, or 20 per cent., of the patients in this series were living when the last follow-up data were obtained, but their tumors had recurred. Symptoms had been present for from five months to ten years before the patients first were operated upon; the average duration of symptoms was 3.8 years. The period covered by the follow-up study varied from ten months to twenty-one years, averaging seven years. A little more description is given of five of these cases, to indicate the conditions encountered. In one patient there was evidence of a recurrence of the tumor on each of two occasions on which he returned within a year after operation; but in a letter received recently, twenty years after the operation, the patient reported that he was well. A second patient, in whom postoperative roentgenographic examination disclosed a fragment of osseous tissue, returned for a check-up thirteen years later. At this time, the fragment apparently was increasing in size. In a third patient, two operations had been performed elsewhere in 1937 and 1938, three were performed at the Clinic in 1939 and 1940, and two were performed elsewhere in 1942 and 1943. In a fourth patient an attempt was made to remove the tumor in 1939; the patient reported by letter in 1943 that his symptoms had returned. Another patient, who had been operated upon elsewhere in 1938 and upon whom we performed extirpation in 1940 and rhizotomy in 1941, was still living, although bedfast, in 1943.

In two, or 5 per cent. of the forty cases, not all of the tumor was removed. One of these patients is still living, sixteen years after the operation. The other patient was having "little trouble" when last heard from, thirty-three months after the operation.

Recurrence of the tumor cannot be regarded as a sign of malignancy. It has been pointed out that thorough and complete removal of these tumors is at times very difficult. If removal is incomplete, recurrence is sure to follow, although not necessarily as the result of malignant degeneration.

No follow-up data were obtained on six (15 per cent.) of the forty patients. One of these patients was operated upon in 1940, and the other five in 1943. In one case, operation was performed solely to obtain material for biopsy.

In fifteen, or 37.5 per cent., of the cases, there was no evidence of recurrence when the

patients last wrote or were seen at the Clinic. The interval between the last operation and the time the last follow-up data were obtained varied from six months to sixteen years, averaging 6.7 years. This group includes the patient upon whom thirteen operative procedures were performed, five patients who received cauterization, one patient who received postoperative irradiation, and one patient upon whom an interinnomino-abdominal (hindquarter) amputation was performed for a recurrent chondroma (Fig. 3-A). Ten months after the amputation the patient reported that he was well.

Definite malignant changes were not found at the first operation, but were ultimately found in the lesions of four, or 10 per cent., of the patients. In one case a diagnosis of osteochondroma was made at the first operation, and a diagnosis of mixed-cell sarcoma was made at the second operation, ten months later. In another patient, three surgical procedures had been performed elsewhere, and a diagnosis of chondroma was made at the time of operation at the Clinic. Three more operations were subsequently performed elsewhere. The patient then returned, and roentgenographic examination revealed a local recurrence and metastatic involvement of the lung. The third case was diagnosed as osteochondroma, and operations were performed. A diagnosis of chondromyxosarcoma was made at the time of the third operation. In the fourth case, biopsy was performed and the tissue was diagnosed as chondroma. The patient died a year later, however, and sections sent to us of lesions in the pelvis, lungs, and omentum disclosed fibromyxochondrosarcoma, Grade 3, according to the classification of Broders.

These four cases are the only ones in which an original microscopic diagnosis of chondroma was made, to be followed later by a diagnosis of some type of malignant tumor. It might be argued that in many such cases the tissue would present the picture of benign chondroma in some places, but definite malignant changes might be seen elsewhere. Proof of the actual mutation of the tumor from a benign to a malignant status cannot be given.

In addition to these forty cases, sixteen patients were observed during the same period (1910 through 1943) in whom malignant chondromatous lesions of the pelvis were present when the patients first were operated upon at the Clinic. In another case, examination of a specimen which was sent to the Clinic disclosed a malignant lesion. The type of malignant lesion was as follows: chondrosarcoma in nine cases, osteochondrosarcoma in two cases, osteochondromyxosarcoma in two cases, sarcoma in one case, fibrochondrosarcoma in one case, and fibromyxochondrosarcoma in two cases.

Twelve of these seventeen patients have died. The period of survival after operation at the Clinic varied from one and one-half to sixty months; the average period was 13.6 months. The duration of life from the onset of symptoms varied from five to ninety-six months; the average duration was 28.4 months.

Five of the seventeen patients were living when information about them was last obtained. One patient, who had had symptoms for five years before operation, wrote that he was in "perfect health" 6.25 years after removal of a chondrosarcoma, Grade 1. Another patient, who had had symptoms for two years before operation, was feeling well when seen again at the Clinic, five years and three months after the removal of a chondrosarcoma, Grade 1. A third patient had had symptoms for three years, and biopsy revealed a chondrosarcoma, Grade 2. This patient was living, but unable to walk, four years later. A fourth patient, after having had symptoms for five years, underwent an interinnomino-abdominal (hindquarter) amputation for chondrosarcoma, Grade 1. Seven months later he reported that he had gained twenty-five pounds. One patient, who had had symptoms for eight years prior to the removal of a chondrosarcoma, Grade 2, reported that he was in "excellent health" eighteen months later.

SUMMARY AND COMMENT

This study is based on forty cases of osteochondroma observed at the Mayo Clinic from 1910 to 1943, inclusive. In each case, the diagnosis was verified by microscopic

examination. A total of sixty-nine operations were performed on these patients. Nine of the patients are known to have died, and eight are known to have had one or more recurrences. In two cases, not all of the tumor was removed at the time of operation. In fifteen cases, there was no evidence of recurrence when the last follow-up data were obtained. No follow-up data were obtained in six cases.

In four of the forty patients, definite malignant changes were later found in the lesions. In sixteen patients (not included among the forty), microscopic examination revealed that the lesions were malignant at the time the patients were first operated upon at the Clinic.

From the foregoing review, the complexity of this problem is obvious. Chondromata of the pelvis must always be considered as serious surgical lesions. This is particularly true of those that are not well pedunculated, and of those in the more remote and inaccessible parts of the pelvis. When the tumor is purely cartilaginous in nature, the diagnosis may be extremely difficult. We have seen at least two cases in which the symptoms were referable to the hip, and, in spite of biopsies with negative findings, the symptoms continued and ultimately a chondroma was revealed. If the tumor is on the inner side of the innominate bone, particularly if it is within the true pelvis, its complete local removal is often difficult or impossible.

The idea is prevalent that these tumors may go from a benign to a malignant status, and in many cases this would seem to be true. However, in some of the cases described this change has not taken place, in spite of several recurrences and operations. In other instances, the presence of both benign and malignant regions in the same tumor may explain the apparent discrepancy.

The importance of complete surgical removal is evident to any one who has seen one or two of these patients in the late stage, when the tumor has reached a huge size, with a great deal of pain and discomfort, and there is little to offer in the way of relief. In those instances in which such removal cannot be accomplished by local excision, interinnomino-abdominal (hindquarter) amputations may be indicated.

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LATE RUPTURE OF EXTENSOR POLLICIS LONGUS TENDON FOLLOWING COLLES'S FRACTURE

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Spontaneous rupture of the tendon of the extensor pollicis longus muscle is always rare, but when such a rupture occurs late, following a Colles's fracture, it is even more unusual. In 1936 the writer saw a patient with a Colles's fracture, in whom a spontaneous rupture of the extensor pollicis longus tendon subsequently developed. Since that time he has seen four similar cases on the Fracture Service of the Presbyterian Hospital, New York City, and subsequently has operated upon all of these patients. In view of the rarity of this complication, and the disability that ensues unless the tendon is operated upon, these five cases are reported in some detail, as to incidence of occurrence, etiology, types of operative repair, and the end results. A brief survey of the literature on the subject is also included.

CASE REPORTS

CASE 1. K. H., a housewife, aged sixty-five, was first seen on May 11, 1936, eleven days after she had sustained a Colles's fracture of the left wrist. The fracture had already been reduced and splinted Roentgenographic examination revealed good reduction, with mild dorsal comminution of the lower end of the radius (Fig. 1). On the twenty-sixth day after injury, the patient complained of pain in the dorsum of the wrist, following an injury on a bus the previous day when her purse jerked on this thumb. She was unable to extend her thumb. Examination disclosed no alteration in the alignment of the bones, but there was complete lack of power of extension in the distal phalanx of the thumb. Extension of the other fingers was normal. There was no loss of sensation in the radial-nerve distribution.

At operation on June 4, the extensor pollicis longus tendon was found to be ruptured. The distal end of the tendon was sutured to the tendon of the extensor carpi radialis longus. The thumb was immobilized in extension for two weeks, and then active exercises were begun. After three weeks the thumb no longer drooped, and the patient could actively extend the distal phalanx. When last seen, five months after operation, she had full use of the thumb and hand. Abduction of the thumb was complete; extension was twenty-five per cent. of normal, and flexion was complete without pain. In spite of the lack of full extension of the thumb, the patient was able to get it away from the side of her hand, which she could not do prior to operation. She had no power to elevate the thumb dorsally to the level of the remaining metacarpals.

CASE 2. I. M., a thirty-year-old cook, was first seen on January 19, 1938, one day after she sustained a Colles's fracture of the left wrist. Roentgenographic examination showed a fracture, with impaction and dorsal angulation (Fig. 2). The fracture was reduced and immobilized in a sugar-tong molded splint for five weeks, followed by hot soaks and frequent active exercises. One week later the

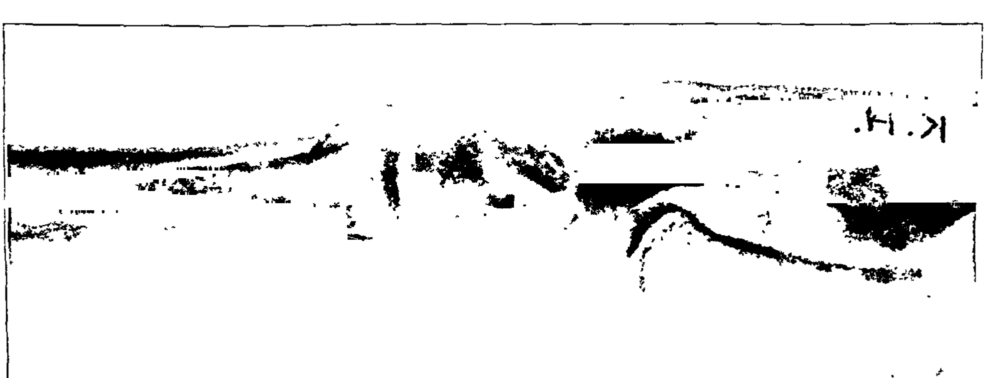

FIG. 1

Case 1. Lateral roentgenogram of left wrist after reduction of fracture.

FIG. 2

Case 2. Lateral roentgenogram of left wrist, showing fracture, with impaction and dorsal angulation.

patient noted weakness in her thumb and inability to extend it, but she did not return to the Fracture Clinic for another seven weeks. Examination showed that the patient was unable to extend the distal phalanx of the thumb, although abduction and extention of the proximal phalanx were possible. The entire thumb drooped, and she could not raise it toward the dorsum of the hand.

At operation on April 25 (seven weeks after rupture), the distal end of the ruptured extensor pollicis longus tendon was sutured to the tendon of the extensor pollicis brevis. The thumb was immobilized in extension for three weeks, and then hot soaks, active exercises, and massage were started. Seven weeks after operation, ability to flex and extend the distal phalanx actively was good. Seventeen months after operation these motions were still good, although extension was slightly weak. The patient was able to carry on full work as a cook, and noted only slight difficulty in lifting heavy pots. She was not able to elevate the entire thumb dorsally to the level of the other metacarpals quite as well as on the right hand.

CASE 3. M. W., a housewife, aged forty-six, was first seen on February 16, 1939, nineteen days after sustaining a fracture of the right wrist. She had received no treatment other than hot soaks. Roentgenographic examination revealed a mild deformity, typical of a Colles's fracture (Fig. 3). No reduction was performed, but the patient was advised to continue with soaks and to start frequent active exercises and mild use. On the following day, while exercising, she felt a "snap" in the wrist, followed by pain and inability to extend the thumb. Examination showed that the right thumb drooped; she was unable to extend the tip against resistance and could not elevate the thumb toward the dorsum of the hand. A loose nubbin was felt on the ulnar side of the antomical "snuffbox", which was thought to be the end of the ruptured extensor pollicis longus tendon. Radial-nerve sensation was normal.

At operation, the day after rupture, the distal end of the extensor pollicis longus tendon was su-

FIG. 3

Case 3. Lateral roentgenogram of right wrist, showing mild deformity.

tured to the extensor pollicis brevis and the abductor pollicis longus tendons. After immobilization in a molded plaster splint for twenty-three days, active exercises and soaks were given. Four weeks after operation the patient sustained a fracture of the radial styloid in the same wrist, but the tendon repair was not harmed. Two months after operation she could touch the middle of her fifth finger with the thumb, but extension of the thumb was not good. At thirteen months she had complete use of the wrist and thumb. When last seen, almost six years after operation, extension of the distal phalanx was full and strong. Dorsal elevation of the thumb was fifty per cent. of normal. The patient does housework with no handicap except difficulty in picking up pins and other small objects.

CASE 4. M. M., a waitress, twenty-one years of age, was first seen on May 26, 1939, two months after sustaining a Colles's fracture of the left wrist. Deformity was so mild that she had not previously sought treatment. One month after the injury, she noticed inability to raise or straighten her left thumb, and there was slight pain at the base of the thumb. Examination revealed that the left thumb drooped, and the patient was unable to extend either the thumb as a whole, or the distal phalanx, against resistance, or to elevate the thumb toward the dorsum of the hand. Roentgenographic examination showed a healed Colles's fracture with minimal deformity (Fig. 4-A). The lower end of the extensor pollicis longus tendon could be felt and moved around beneath the skin by the examiner's finger.

At operation on June 18, the distal end of the ruptured extensor pollicis longus tendon was sutured to the extensor carpi radialis longus and the extensor pollicis brevis tendons. The thumb was immobilized for four weeks in a molded splint, but, beginning eight days after operation, this was removed three times daily for soaks and exercises. At seven weeks the patient had excellent active flexion and extension of the distal phalanx, and could abduct, extend, and elevate the thumb well. She returned to work at this time. Five and one-half years after operation, the patient's only complaint was slight pain in the region of the repaired tendon after protracted use. Active extension of the distal phalanx was full and powerful. She could elevate the thumb dorsally almost as well as its fellow, and could

FIG. 4-A

Case 4. Lateral roentgenogram of left wrist, showing healed fracture.

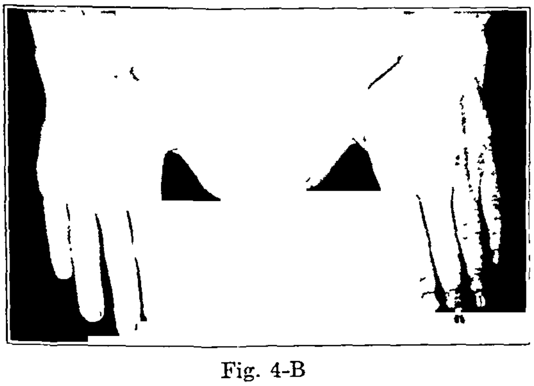

Fig. 4-B

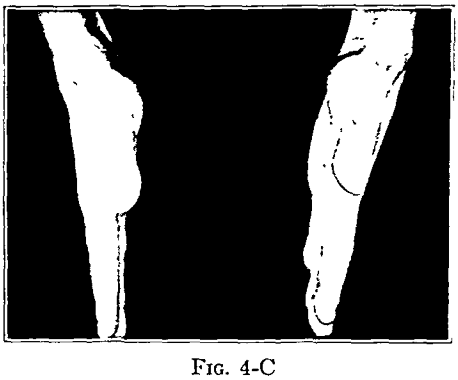

FIG. 4-C

Both hands, five and one-half years after operation. Note full extension and dorsal elevation of left thumb, as compared with normal side.

touch the base of the fourth finger with it. Picking up pins caused slight difficulty. The patient now runs a sewing machine in a factory, with only slight handicap (Figs. 4-B and 4-C).

CASE 5. I. M., a factory worker, aged fifty-five, was first seen on July 10, 1943, one hour after she sustained a Colles's fracture of the left wrist. Roentgenographic examination revealed slight dorsal tilt, displacement, and radial deviation of the distal radial fragment (Fig. 5-A). The fracture was reduced, and immobilized in a sugar-tong plaster splint for twenty-six days. At this time, while exercising her

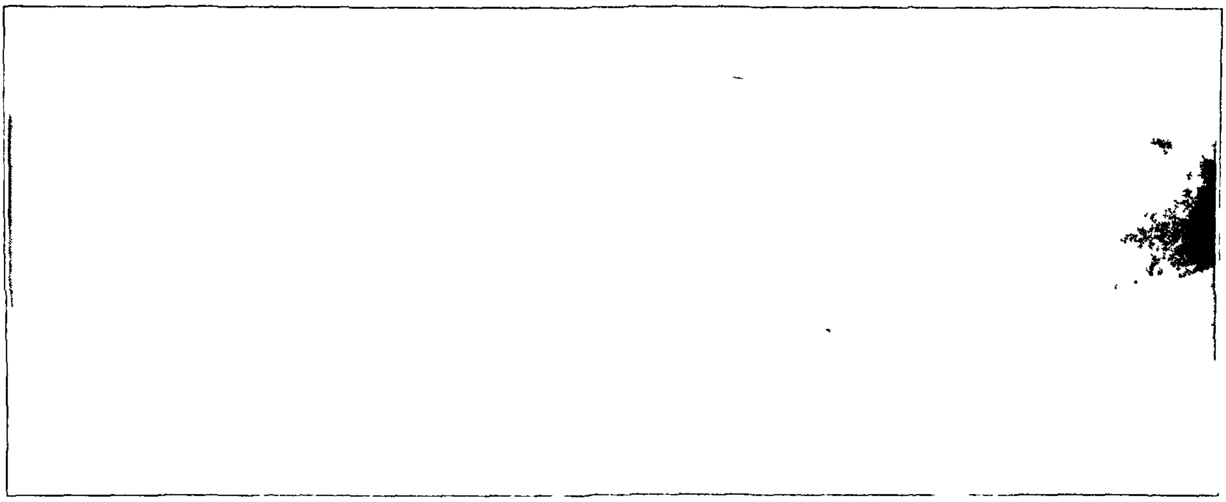

FIG. 5-A
Case 5. Lateral roentgenogram of left wrist immediately after fracture.

FIG. 5-B
Both hands in pronation prior to operation. Note visible absence of extensor pollicis longus tendon in left wrist.

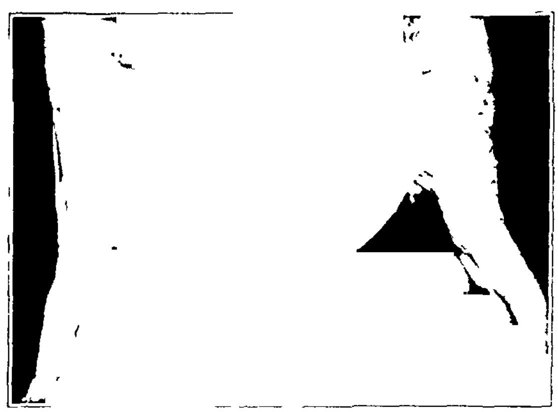

FIG. 5-C
Both hands in mid-rotation prior to operation. Note drooping of left thumb and ill-defined snuffbox.

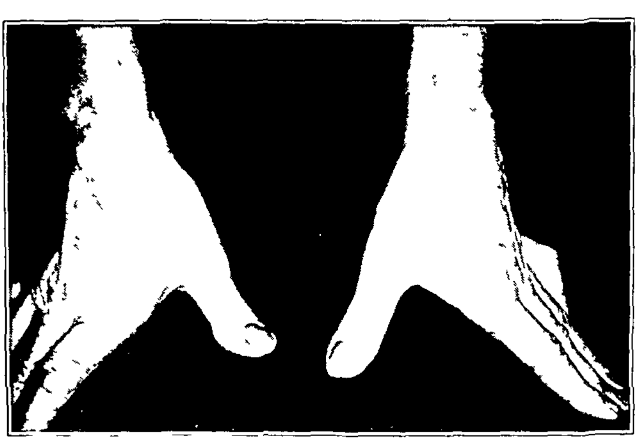

FIG. 5-D

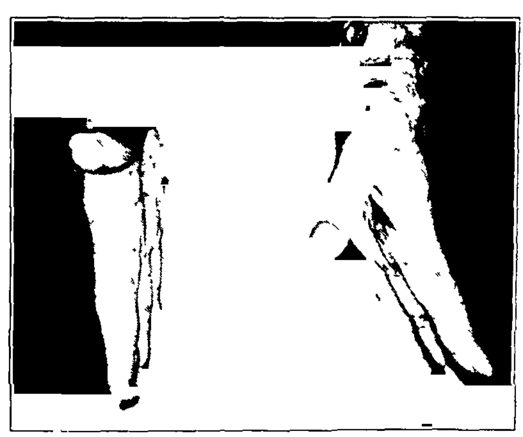

FIG. 5-E

Both hands, thirteen months after operation. Extension of distal phalanx of thumb is complete, but power of dorsal elevation of entire thumb has been only partially corrected.

wrist and fingers, the patient felt a "snap" in her thumb and was unable to extend it thereafter. Examination three days later showed complete loss of action of the extensor pollicis longus tendon, with inability to extend the tip of the thumb or to elevate it dorsally (Figs. 5-B and 5-C).

At operation, seventeen days after rupture, the distal end of the ruptured extensor pollicis longus tendon was sutured to the extensor pollicis brevis and the extensor carpi radialis longus tendons. The thumb was then immobilized in full extension for twenty-two days; this was followed by soaks and exercises, and, at the end of four weeks, by light use. The patient could touch all finger tips with the thumb at the end of five weeks, and could elevate the thumb nearly to the level of the other metacarpals. She returned to work at the end of two months. Thirteen months after operation, extension of the distal phalanx of the thumb was complete, and ability to elevate the thumb dorsally was about fifty per cent. of normal. Abduction and adduction of the thumb were normal. The patient was carrying on her regular work in a factory (Figs. 5-D and 5-E).

REVIEW OF THE LITERATURE

McMaster, in 1932, reported a case of late rupture of the extensor pollicis longus tendon following Colles's fracture, and was able to find only twenty-seven similar cases mentioned in the literature. He also discussed a case of late rupture of the flexor pollicis longus tendon after Colles's fracture, which was the only case of its kind reported. This excellent article gives a very good historical review of the subject and a very complete bibliography. Lapeyre collected fifty-one cases of rupture of the extensor pollicis longus tendon in the literature, thirty-nine of which had followed fracture of the lower extremity of the radius (probably Colles's fracture). Kwedar and Mitchell found seventy cases in the literature, and added one case of their own which followed Colles's fracture. The first case was reported by Duplay in 1876. In the German literature are found a great many reports of spontaneous rupture of the extensor pollicis longus tendon, not preceded by fracture of the lower radius, which occurred in drummer boys in the army. This condition at first was known as "*Trommlerlähmung*", or drummer's palsy; it remained for Düms to show that it was not a palsy, but a spontaneous rupture of the extensor pollicis longus tendon due to chronic tenosynovitis, caused by this particular occupational trauma. So-called drummer's palsy is probably the commonest cause of rupture of this tendon, if industrial accidents, such as lacerations, are excluded.

ETIOLOGY

The etiology of rupture has not been definitely established, but it probably follows rather late after acute or chronically repeated trauma. The trauma causing the fracture could, by producing a spicule of bone, bring about partial laceration of the extensor pollicis longus tendon in its groove on the dorsum of the radius. A certain amount of bony comminution is frequent on the dorsal aspect in Colles's fracture, and a sharp fragment might easily cause chronic trauma and attrition as the tendon rubs back and forth over it. Forceful reduction of the fracture could conceivably be another cause of trauma to this tendon, but numerous cases of rupture have been reported where the fracture was minimally displaced or unrecognized, and no reduction had been done (Table I). Interference with the blood supply of the tendon (via the mesotendon) has been considered by many as the chief cause of late rupture. At the time of fracture, or shortly thereafter, the mesotendon is lacerated and its vessels may become thrombosed. The tendon at this site undergoes aseptic necrosis which causes softening, swelling, and gradual loss of strength, until such time as a slight sudden strain causes it to rupture. McMaster has shown experimentally that a normal tendon does not rupture under severe strain, unless it has been lacerated halfway through its substance. He also showed that late ruptures could be brought about by strain at the site where the blood supply to the tendon itself had previously been shut off by ligation of the tendon at two points, one centimeter apart. Diseased tendons frequently undergo spontaneous rupture, due to tuberculous tenosynovitis, gonorrheal tenovaginitis, or chronic non-specific tenosynovitis, as in "drummer's palsy". It is

TABLE I
RUPTURE OF EXTENSOR POLLICIS LONGUS TENDON

Case No.	Dorsal Comminution at Fracture Site	Fracture Reduction	Occurrence of Rupture in Relation to Use of Splint		
			During Use	After Discard	No Splints Used
1	Slight	Done	x		
2	Moderate	Done		x	
3	Absent	Not Done			x
4	Absent	Not Done			x
5	Slight	Done	x		

the writer's belief that, in rupture following Colles's fracture, the cause is an aseptic necrosis, due to interference with the blood supply of the tendon at the distal end of its groove on the radius. The operative and pathological findings in the five cases presented here would seem to bear out this assumption.

SYMPTOMS

There are no symptoms prior to rupture which would lead the surgeon to suspect a degenerative process in the tendon. Even when the tendon ruptures, not all patients give a history of pain. A few describe a single sharp pain, but most describe what they call a sensation of "something giving way", or a "snap" on the back of the wrist, followed by inability on their part to straighten or to lift the thumb actively, as compared with the normal thumb. They may also note difficulty in picking up small objects, such as pins. No subjective sensory changes are noted.

PHYSICAL SIGNS AND DIAGNOSIS

Physical examination reveals, first, a thumb that droops in its entirety, and, second, partial flexion of the distal phalanx. There is a normal droop to every thumb when the hand is examined in repose. With an intact extensor pollicis longus tendon, however, the patient can actively elevate the thumb to the same level as the other metacarpals or even higher; with a ruptured tendon this is impossible. It is also impossible for him to extend the distal phalanx actively against resistance, although this can be done passively. Therefore, one can easily understand how the early German writers considered the condition occurring in drummers to be a palsy. The inability of the patient to extend the distal phalanx of the thumb, in the presence of a ruptured tendon, has been noted by all writers on the subject, but few have described the tendency of the thumb as a whole to droop. When the normal hand is opened fully, and an attempt is made to spread the thumb and all fingers widely apart, the taut tendon of the extensor pollicis longus can very readily be visualized and palpated as the ulnar border of the anatomical snuffbox. With a ruptured tendon, this boundary is characteristically absent. Occasionally the swollen, degenerated end of the distal portion of the ruptured tendon can be felt beneath the skin and subcutaneous tissue as a small bump, often described as a nubbin. There is no loss of skin sensation over the superficial radial-nerve distribution. A paralysis or palsy of the posterior interosseous (deep radial) nerve would, of course, make it impossible for the patient to extend the second to the fifth fingers, inclusive, at the metacarpophalangeal joints, and would also affect extension of the thumb. Therefore, the diagnosis should not be difficult, if one keeps in mind that late rupture of the extensor pollicis longus tendon may occur many weeks after Colles's fracture.

SITE OF RUPTURE

The site of rupture in the extensor pollicis longus tendon is usually at the level of Lister's tubercle, on the dorsum of the lower extremity of the radius. The distal portion of the ruptured tendon is usually drawn downward, and may even be doubled back on itself. It is completely relaxed, and therefore does not stand out prominently as the ulnar border of the anatomical snuffbox. The tendon end is frequently adherent to its sheath and to the surrounding structures, and may be encircled by new vascular connective tissue, depending somewhat upon the duration of the rupture prior to operative exploration. The proximal portion of the ruptured tendon usually retracts upward, so that its end is either at the upper edge of the dorsal radiocarpal ligament, or even more proximal to this. As much as five centimeters sometimes separate the two tendon ends. This proximal end is also bound down with adhesions, and the groove on the dorsum of the radius, through which it passes, becomes obliterated. The end of the distal tendon stump is usually somewhat swollen, bulbous, yellower than normal, and lacks the luster of a normal tendon. Sometimes this end may be ecchymosed and actually softer than the normal tendon. Microscopic examination of the excised degenerated end of these tendons shows hyaline degeneration of the tendon fibers; and there is often infiltration with lymphocytes, fibroblasts, and, occasionally, granulation tissue. One specimen, when stained with *Scharlach R*, showed the presence of fat between the tendon fibers.

LATENT PERIOD OF RUPTURE

The average period between fracture and the rupture of the extensor pollicis longus tendon is said by Kwedar and Mitchell to be six weeks; McMaster states that it usually occurs between the third week and the third month. In the five cases reported in this article, the earliest rupture occurred twenty days, and the latest six weeks, after fracture; the average latent period for the five cases was twenty-nine days.

INCIDENCE OF RUPTURE

The ratio of rupture of the tendon after fracture to the total number of Colles's fractures is said by Pörsch, Oppolzer, and Horwitz to be 1 to 270. On the Fracture Service of the Presbyterian Hospital, 1,341 Colles's fractures were treated between 1929 and 1943, inclusive. In five of these cases, there was subsequent rupture of the extensor pollicis longus tendon, giving a ratio of 1 to 268. The majority of ruptures have occurred in the left wrist. Kwedar and Mitchell, in reviewing the literature, found the complication more frequent in females (sixty per cent.). All five patients whose histories are reported in this article were females. The tendon rupture may be seen at practically any age, but is more common after thirty years. The youngest patient was reported by Lülsdorf, and was a girl of fourteen years.

In two of the five cases reported here (Case 3 and Case 4), the patients sought treatment late, that is, nineteen days and two months, respectively, after their falls. Neither patient suspected she had a fracture before coming to the Clinic. Since in neither case had the fracture been reduced or the wrist splinted, it is impossible to consider rough manipulation or faulty splints as a predisposing cause of the tendon rupture. In Case 3 the tendon ruptured almost under our own eyes, the day after the patient's first visit to the Clinic, while she was carrying out finger and thumb exercises.

FUNCTION

The extensor pollicis longus tendon has a dual function. This is poorly understood or completely ignored by the textbooks of anatomy. They point out that this tendon inserts on the dorsum of the base of the distal phalanx of the thumb, and that its action is to extend the distal phalanx upon the proximal phalanx at the interphalangeal joint. This

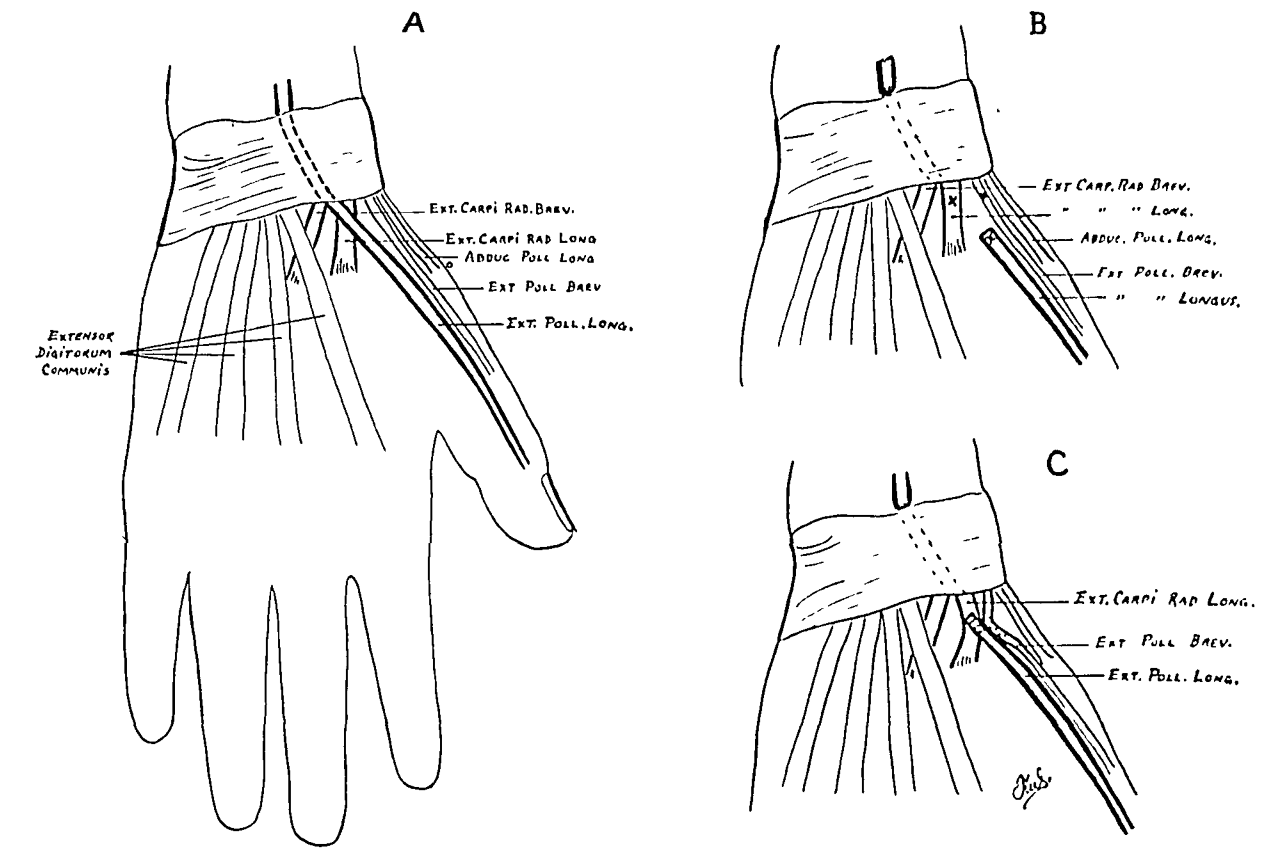

Fig. 6

A: Normal relations of tendons at dorsum of wrist and thumb.
B: Relation of tendons after rupture of extensor pollicis longus tendon.
C: Hook-up of extensor pollicis longus tendon to restore obliquity of its pull, as suggested by the author.

is only half of this tendon's function, and, in the writer's opinion, the less important half. In describing the deformity of the thumb with a ruptured extensor pollicis longus tendon, it was stated that the thumb drooped as a whole. This drooping of the thumb is due entirely to the loss of the *oblique* pull of the tendon. Neither the extensor pollicis brevis tendon nor the abductor pollicis longus tendon, nor both together, can overcome this droop when the extensor pollicis longus is ruptured. Any operative procedure designed to restore full function must therefore restore the obliquity of its pull (Fig. 6). If this very important half of its function is not restored, the patient will be able only to extend the distal phalanx but not to lift the thumb, and consequently will be handicapped in many activities.

OPERATIVE REPAIR

The ideal method of repair would be by resuture of the ruptured tendon ends directly, or by implantation of a free tendon graft between the ends. This would restore the normal continuity of the ruptured tendon, and replace it in its normal position. However ideal this would seem mechanically, it requires much freeing of adhesions; the resultant bleeding would give rise to more and denser adhesions during postoperative immobilization, which would "freeze" the tendon and make it non-functioning. In Case 1, although restoration of the obliquity of the pull of the extensor pollicis longus was accomplished by suturing the distal stump to the tendon of the extensor carpi radialis longus, the writer now considers this a mistake, because of the short excursion of the latter tendon due to the proximity to its insertion. If the distal end of the extensor pollicis longus is sutured to the extensor pollicis brevis, to the abductor pollicis longus, or to both, only active extension of the distal phalanx of the thumb will be restored, as mentioned heretofore. At the present time, following experiences with the first three cases, the writer feels that the most satisfactory hook-up to restore both functions is to suture the distal end of the extensor pollicis

TABLE II
REPAIR OF RUPTURED EXTENSOR POLLICIS LONGUS TENDON

Case No.	Tendons to which Distal Extensor Pollicis Longus Tendon Was Sutured	Restoration of Function of Thumb
1	Extensor carpi radialis longus	+
2	Extensor pollicis brevis	+++
3	Extensor pollicis brevis and abductor pollicis longus	++
4	Extensor carpi radialis longus and extensor pollicis brevis	++++
5	Extensor pollicis brevis and extensor carpi radialis longus	++

longus to the extensor carpi radialis longus by an end-to-side suture; following this, the tendon of the extensor pollicis brevis is drawn over to it and sutured additionally by a side-to-side suture. No. C silk is sufficiently large and strong, if three or four mattress-type sutures are used at each junction (Fig. 6). The thumb should be held in full extension and elevated dorsally while its long extensor tendon is being sutured to the extensor carpi radialis longus. This first hook-up gives the lift to the thumb, and the extensor pollicis brevis adds extension to the distal phalanx. Table II summarizes the method of repair in the five cases, and the results of the dorsal lift secured.

The writer has not used the method of repair described by Biesalski and Mayer, in which the tendon of the extensor indicis proprius, or half of it, is transplanted and sutured to the distal stump of the extensor pollicis longus. This method seems logical, but would appear to have the drawback of lack of obliquity of its groove in the dorsum of the radius. By making this tendon take over the oblique pull of the extensor pollicis longus, a tenosynovitis might conceivably result as it is pulled around a sharp corner. However, no one person has used enough of these various methods to be in a position to lay down positive rules as to the proper method of repair. The advantage of the method advocated by the writer is simplicity of technique without extensive additional dissection, and without the possibility of weakening the extension of the index finger.

It is important, when exploring and repairing the tendon, to isolate and protect the superficial branch of the radial nerve, since damage to this nerve may lead to distressing numbness of the dorsum of the thumb.

POSTOPERATIVE CARE

Following operative closure, the hand, wrist, and forearm should be immobilized in a volar molded plaster splint in slight cock-up position, with the thumb fully extended and elevated. The patient may leave the hospital on the third or fourth postoperative day. Skin sutures are removed after one week. The splint may be removed at the end of ten days, and the patient is encouraged to begin moving the thumb very gently in flexion and extension. He should then be advised to remove the splint three or four times daily for exercises and for hot soaks. Usually at the end of three weeks, or at most four weeks, it is possible to discard the splint completely. The exercises are then increased, and the patient is encouraged to begin mild active use of the thumb. By this method, the thumb is protected from sudden violent motions during the period of healing of the repaired tendon; yet, if gentle motion is started early, it should prevent the formation of dense adhesions which might later "freeze" the tendon motion.

FOLLOW-UP RESULTS

Unless operative repair of the ruptured extensor pollicis longus tendon is carried out, there can be no expectation of improvement in function of the thumb. It is gratifying to note that in all of the reported cases, after repair of the tendon, the patients showed im-

TABLE III

CLINICAL SUMMARY OF FIVE CASES OF RUPTURE OF EXTENSOR POLLICIS LONGUS TENDON

Case No.	Age	Sex	Occupation	Side	Date of Fracture	Time Intervals					Results
						Latent Period of Tendon Rupture	From Rupture to Operation	Period of Post-operative Splinting	Repair to Active Motion	Operation to Last Follow-up	
1	65	F	Housewife	L	Apr. 30, 1936	25 days	10 days	2 weeks	2 weeks	5 months	Fair to good
2	30	F	Cook	L	Jan. 18, 1938	6 weeks	51 days	3 weeks	3 weeks	17 months	Good to excellent
3	46	F	Housewife	R	Jan. 28, 1939	20 days	1 day	23 days	23 days	5 years, 9 months	Excellent
4	21	F	Waitress	L	Apr. 26, 1939	4½ weeks	7 weeks	4 weeks	8 days	5½ years	Excellent
5	55	F	Factory worker	L	July 10, 1943	27 days	17 days	22 days	22 days	13 months	Good
Average Time						29 days	17 days	3 weeks	3 weeks		

provement both in function and in use. The best follow-up results from a functional standpoint were found in those cases in which, in addition to restoration of the active extension of the distal phalanx, an attempt was made to restore the obliquity of pull of this tendon and thereby improve the patient's ability to elevate the thumb. All of the patients mentioned in this paper have been able to return to their previous occupations following operative repair of the tendon, with very little subjective handicap (Table III).

CONCLUSIONS

1. Late spontaneous rupture of the extensor pollicis longus tendon following Colles's fracture is a rare complication, and one that is not often recognized. This paper adds five cases to those previously reported in the literature.
2. The rupture is, in all probability, due to aseptic necrosis of the tendon, following injury to its blood supply.
3. The history and physical signs are very characteristic.
4. Return of function without operation cannot be expected. With operation, a good to excellent return of function may be expected.
5. Stress has been laid upon the dual function of the *oblique* pull of the extensor pollicis longus tendon, and a method of repair has been suggested to accomplish this functional restoration.

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ORTHOROENTGENOGRAPHY AS A METHOD OF MEASURING THE BONES OF THE LOWER EXTREMITIES

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Accurate measurement of the length of the lower extremities is often indicated. For many purposes clinical measurements suffice, but they are admittedly grossly inaccurate. The usual method of teleoroentgenography, although allowing more accurate records of comparative lengths, produces an increasing degree of magnification and distortion as the extremities grow (Fig. 1-A).

In a study of growth by the Harvard Infantile Paralysis Commission, it was found necessary to develop a method of measuring the lower extremities which would meet the following requirements:

1. Measurement of the bones should be sufficiently accurate to record the comparative true lengths at any one examination.
2. The precision of measurement should remain constant for varying bone lengths, in order to compute accurately the true increments of growth.
3. Sufficient detail should be delineated to allow the detection of abnormalities in the bones and visualization of the epiphyseal lines.

The method to be described has been designated "orthoroentgenography". It has met these requirements while in use over a period of four years, during which time over 2,200 recordings have been made.

METHOD

The method employs three separate exposures for the lower extremity (Fig. 1-B). The central ray is directed successively over each of the three joints, and the three exposures are processed on a continuous film,* fourteen inches in width and of any desired length up to forty-four inches. The technical factors may be varied between exposures, according to the thickness of the soft tissue over each part. A target-to-film distance of six feet is always used.

A tunnel for a long cassette (fourteen inches by forty-four inches) has been devised, into which have been incorporated two sliding metal shields (Fig. 2). Such a device allows an exposure to be made over any one third of the film, while the other two thirds are protected from exposure.

The patient is placed on the cassette holder in the supine position, with the hips level and the extremities parallel; straps are fastened over the lower thighs and over the ankles to hold the limbs in the proper position (Fig. 3).

Three exposures are made in sequence. In the first, the tube is centered over the hip joint with both shields in the distal position; in the second, the tube is over the knee joint with one shield in the proximal position and the other in the distal position; in the final exposure the tube is centered over the ankle joint, with both shields in the proximal position.

The centering of the tube in each exposure is checked by a long metal marker, placed horizontally at right angles to the side of the cassette. One end, pointing at the level of the joint to be exposed, extends over the cassette far enough to cast a shadow on the film; the other end indicates the position of the tube stand for the exposure. In this way,

* The film is purchased in rolls seventy-five feet long and stored in metal containers. Just before exposure, the film is cut to the length required for each orthoroentgenogram. The cost for each individual averages $2.10, if a roll of film is purchased and only the necessary length of film is used.

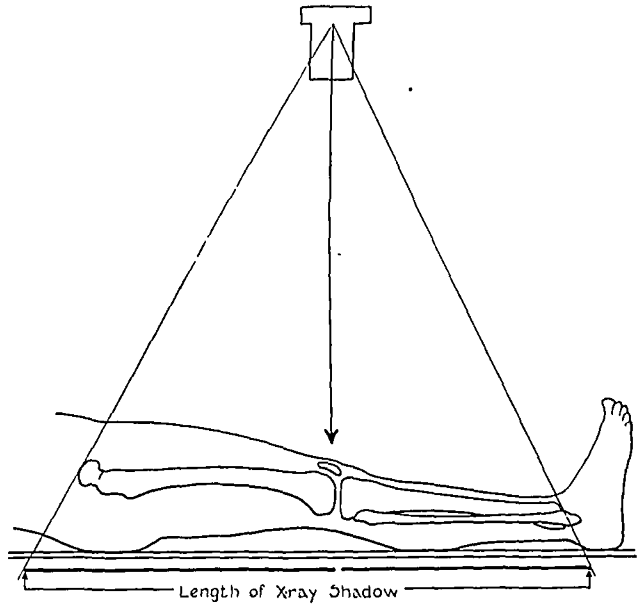

FIG. 1-A

Schematic representation of the relative lengths of shadows of the same bones filmed with a one-exposure and with a three-exposure technique.

Fig. 1-A: Divergent rays produce magnification in teleroentgenography.

Fig. 1-B: Perpendicular rays intersect the ends of the bones in orthoroentgenography, recording the true length.

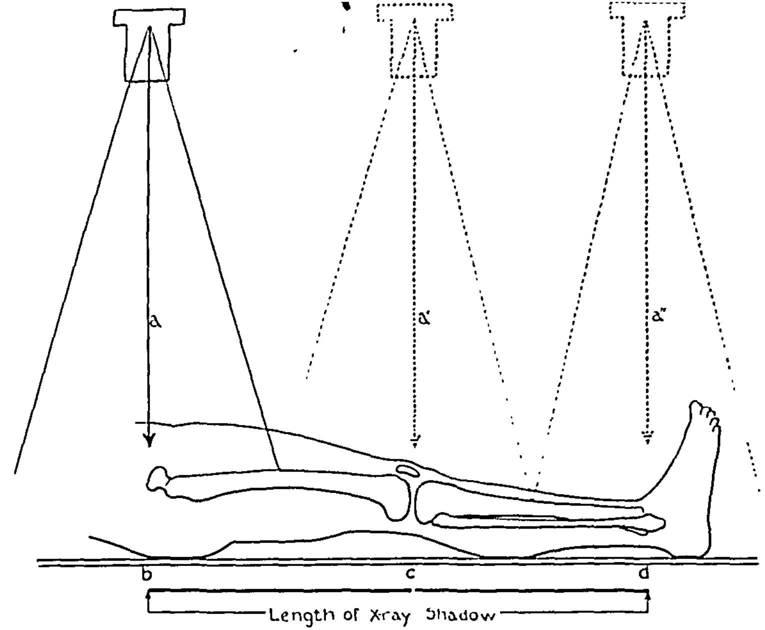

FIG. 1-B

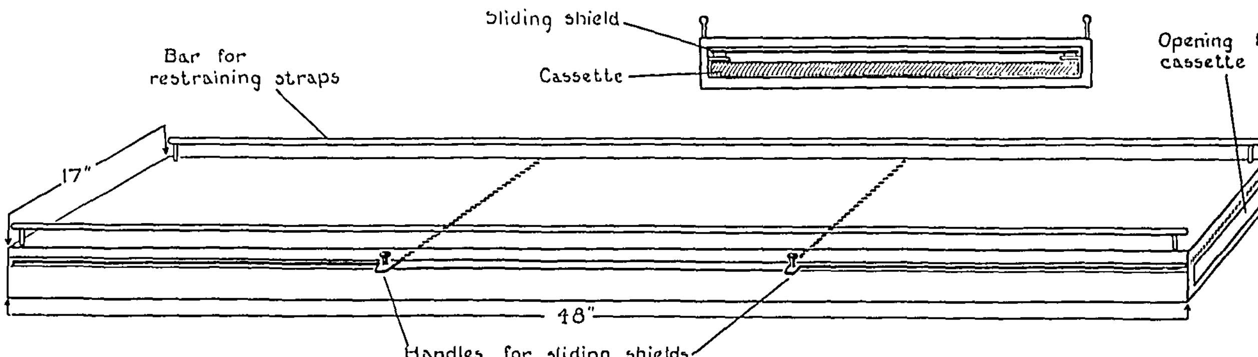

FIG. 2

Fig. 2: Diagram of cassette tunnel used for orthoroentgenograms.

The frame of the tunnel is constructed of welded channel, one and one-half by three inches, which is milled to form suitable grooves in which the cassette may slide and the shields be shifted. On one side of the long dimension of the frame is a narrow slot, through which the handles of the shields protrude. The top is made of polished bakelite, one-eighth of an inch thick, and is fastened to the frame with screws. The shields are made of cold rolled steel and are mounted on tracks in order to be moved alternately into the central opening. Steel rods, one-half inch in diameter, are mounted on either side, one-quarter inch above the bakelite surface, to permit the attachment of restraining straps.

the exact level of focus is permanently recorded on the finished orthoroentgenogra (Fig. 4-B). The distance of six feet from tube to film decreases any slight inaccurac occasioned by imperfect centering.

In teleoroentgenography the divergence of the rays from the tube produces consider able magnification, even when a distance of six feet from tube to film is used. The amoun of magnification is variable, depending upon the length of the bone, the distance of th bone from the film, and the centering of the tube (Table I). Although teleoroentgenogram do not give the true lengths of bones, they do allow fairly accurate estimates of the rela tive lengths of the two extremities at a single examination. If they are used for seria measurements of growth, however, a variable distortion arises which makes them un satisfactory, since the magnification becomes greater with the growth of the individua This increased distortion is produced both by the increase in the bone-to-film distanc resulting from the thickening of the posterior structures, and by the increased length o the bones themselves, which places the bone ends nearer the periphery of the divergin roentgenographic beam.

FIG. 3

Patient in position for orthoroentgenogram. The extremities are steadied by restraining straps, and the cassette is being slid into the tunnel.

In part, the error of magnification in teleoroentgenographic mensuration can be corrected mathematically by triangulation. Difficulties in computation arise from the fact that the two ends of a given bone vary in height from the film. Furthermore, the computations are time-consuming and the results are inaccurate, since the distances of the bones from the film can only be estimated.

The accuracy of the measurements of teleoroentgenograms might be improved by the use of a radiopaque ruler, placed parallel to the bones and at an equal distance from the film, following the principle used in the Thoms method of roentgen pelvimetry. In practice, however, it was found impossible to place the ruler precisely enough to warrant its use. Teleoroentgenography, or one of its modifications, was considered not sufficiently accurate for our purposes.

Merrill described a method which allows more accurate measurement than does teleoroentgenography. He used three exposures on separate films, and measurements were made from a superimposed numbered metallic scale. This method does not allow visualization of the full length of the bones, no technique of checking the accuracy of focus was provided, and the focal distance used was only forty-two inches.

Consideration was given to the use of some adaptation of the slit scanogram.[3] It was decided, however, that an exposure of the necessary length and intensity would be unduly wearing on the roentgenographic tube, and the available equipment precluded any experimentation along these lines. Gill and Abbott have since described a modification of the slit-scanographic technique in the measurement of the bones of the lower extremities. They obtained films of good quality which recorded the exact length of the bones.

TABLE I

COMPARATIVE MEASUREMENTS OF THE LOWER EXTREMITIES IN TWENTY CASES BY ORTHOROENTGENOGRAPHY AND BY TELEOROENTGENOGRAPHY

Variations in the Measured Length of Bones as Obtained from Orthoroentgenograms with Those Obtained from Long Teleoroentgenograms (One Exposure of the Whole Lower Extremity on a Single Film) and from Short Teleoroentgenograms (Separate Films for the Femora and Tibiae)

FEMORA				TIBIAE			
Ortho. (*Cm.*)	Long Teleo. (*Cm.*)	Difference (*Cm.*)	Teleo./Ortho.	Ortho. (*Cm.*)	Long Teleo. (*Cm.*)	Difference (*Cm.*)	Teleo./Ortho.
30.0	31.1	1.1	1.037	20.4	21.0	0.6	1.029
32.4	33.6	1.2	1.037	22.7	23.4	0.7	1.031
34.2	35.5	1.3	1.038	24.0	24.7	0.7	1.029
36.7	38.2	1.5	1.041	26.6	27.3	0.7	1.026
38.4	39.7	1.3	1.031	28.2	29.0	0.8	1.028
40.0	41.5	1.5	1.038	30.5	31.4	0.9	1.030
42.2	43.8	1.6	1.038	32.3	33.2	0.9	1.028
44.7	46.6	1.9	1.042	34.9	35.9	1.0	1.029
46.5	49.3	2.8	1.060	35.6	36.7	1.1	1.031
45.5 *	49.2 *	3.7	1.081	37.0 *	38.5 *	1.5	1.040
Ortho. (*Cm.*)	Short Teleo. (*Cm.*)	Difference (*Cm.*)	Teleo./Ortho.	Ortho. (*Cm.*)	Short Teleo. (*Cm.*)	Difference (*Cm.*)	Teleo./Ortho.
29.4	30.4	1.0	1.034	20.9	21.7	0.8	1.038
32.9	34.3	1.4	1.042	23.4	24.3	0.9	1.038
34.0	35.5	1.5	1.044	25.0	26.0	1.0	1.040
36.8	38.4	1.6	1.043	27.5	28.6	1.1	1.040
38.3	40.2	1.9	1.050	28.7	29.9	1.2	1.042
40.3	42.2	1.9	1.047	30.0	31.4	1.4	1.047
42.2	44.3	2.1	1.050	33.0	34.5	1.5	1.045
43.9	46.2	2.3	1.052	34.4	35.9	1.5	1.044
46.7	49.3	2.6	1.056	37.7	39.3	1.6	1.042
45.5 *	48.2 *	2.7	1.059	37.0 *	38.6 *	1.6	1.043

* Measurements are from roentgenograms of skeletons. Focus on long teleoroentgenogram of skeleton was at the knee; compare magnification with other long teleoroentgenograms, where focus was over the femur.

ORTHOROENTGENOGRAMS

Orthoroentgenograms give a permanent, verifiable record of the lengths of the bones of the lower extremities. Because only perpendicular rays are directed at the ends of the long bones, magnification of length is eliminated, and visualization of each undistorted epiphyseal line is possible. The accuracy obtained with this method is such that increments of length can be reliably measured in growing children over an interval as short as three months.

The true length of each bone can be measured directly from orthoroentgenograms without computation; there is no significant magnification of length due to the divergence of the rays, because the focal spot is placed exactly over each joint.† Special high-speed roentgenographic equipment is not necessary for these films; the strain on the tube is no greater than it would be in filming separately a hip, a knee, and an ankle.

Comparison of the lengths of bones, using orthoroentgenograms and teleoroentgeno-

† Although orthoroentgenograms record the exact distance from one end of the bone to the other, slight shortening would occur if the bone were not parallel to the film. In the femur, for example, a minimal amount of shortening must occur, due to the oblique position of the bone. This could be corrected by elevating the knee and ankle to the same level as the head of the femur. The error involved is, however, so slight that such a procedure was thought undesirable, as it would be overbalanced by the loss of bone detail due to the increased distance of the object from the film.

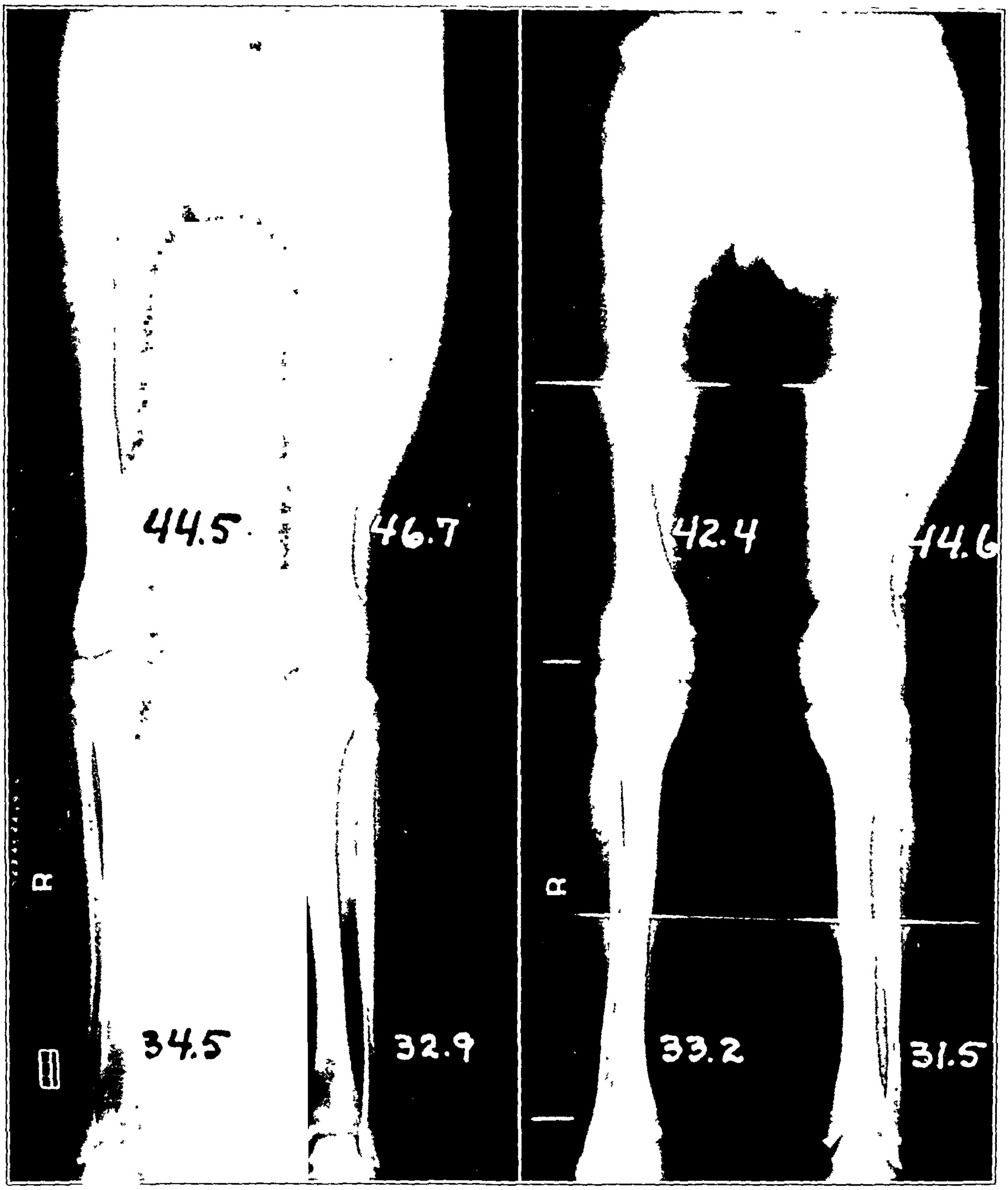

FIG. 4-A FIG. 4-B

Comparative roentgenograms of the same child, taken by two different methods.

Fig. 4-A: In the teleoroentgenogram, note the variability in visualization of the bones. The upper ends of the femora are poorly shown. The combined length of the bones in the right leg is 79.0 centimeters; in the left leg, 79.6 centimeters.

Fig. 4-B: In the orthoroentgenogram, note the greater evenness of visualization. The combined length of the bones in the right leg is 75.6 centimeters; in the left leg, 76.1 centimeters. The difference in extremity lengths, as measured by the two films, is 3.4 centimeters on the right and 3.5 centimeters on the left. This represents the magnification produced in the teleoroentgenogram.

The position of the metal marker can be seen opposite each joint on the right leg; it is much more easily visualized in the original film than in the photographic reproduction.

grams, has always revealed a considerable degree of magnification in the teleoroentgenogram (Table I). This occurs whether the teleoroentgenogram is made on a long film with a single exposure for the entire lower extremity, or on two short films with separate exposures for the femora and the tibiae. The magnification is greater with the longer bones, although it is modified by the relative thickness of the soft tissues, which in turn modify the distance of the bones from the film.

Whereas the magnification of the femur in the long and the short teleoroentgenograms is essentially the same, the tibia shows somewhat less magnification in the long film. This arises from the fact that in the long teleoroentgenogram the tube is centered over the lower femur to provide better visual detail. The rays intersecting the two ends of the femur are thus similarly divergent in the two types of film. However, in the long film, since the tube is centered over the femur, the rays intersecting the upper end of the tibia tend to produce some foreshortening. This illustrates one of the difficulties in the use of teleoroentgenograms for serial study, since variation in the points of focus affects the length of the shadows obtained.

The measurements obtained from orthoroentgenograms show little deviation from the real length of bones. Orthoroentgenographic measurement of a dissected adult femur, 45.7 centimeters long, gave a length of 45.5 centimeters; that of an adult tibia, 37.0 centimeters long, was 37.0 centimeters by orthoroentgenogram. The lengths of these bones, as recorded on a long teleoroentgenogram centered at the knee, were 49.2 centimeters for the femur and 38.5 centimeters for the tibia; on short teleoroentgenograms they were 48.2 centimeters and 38.6 centimeters, respectively. In these exposures the bones were placed at a distance from the film comparable to that which would exist in a patient.

Since the whole of both lower extremities is presented on a single film in an orthoroentgenogram, details of the structure of the bone and any factors of deformity can readily be evaluated. The only loss of visualization is produced by the overlapping of shadows at the junction of the shields, but this point can be placed at the mid-shaft, where it is of little consequence. The amount of bone not visible on the film is that which represents the magnification produced in a teleoroentgenogram.

Some distortion in length can occur in the orthoroentgenogram, if the tube is not centered over the end of the bone. For this reason the exact points of focus are recorded on each film with a metal marker. If the focal spot should be significantly above or below the end of the bone, the film could be repeated. In practice this has seldom been necessary, and the marker serves primarily as a verification of technique.

Motion of the patient between exposures must not occur. This is controlled by placing the patient in a comfortable position, by strapping the legs, and by the vigilance of the technician. If the cooperation of the patient is secured, the factor of motion offers no more difficulty than in any other roentgenographic procedure.

If there is a marked discrepancy in the length of the two extremities, there will be a small amount of relative distortion in the measured length of the bone over which the tube is improperly centered. In such cases, the two extremities may be exposed separately.

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LIGAMENTS OF THE KNEE JOINT

The Relationship of the Ligament of Humphry to the Ligament of Wrisberg

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The ligament of Humphry, and its relation to Wrisberg's ligament of the knee joint, seems to have escaped the attention of many clinical surgeons and not a few anatomists. It seems worth while, therefore, to review briefly this anatomical structure.

George Murray Humphry described the ligament in 1858. He stated that the posterior aspect of the lateral meniscus is attached by fibers that pass in front of or behind the posterior cruciate ligament. Poirier and Charpy, in 1899, wrote that the attachment of the lateral meniscus to the medial condyle of the femur is constant and very strong; it has been considered a third cruciate ligament. At times it separates into two bundles, one of which passes in front of, and the other behind, the posterior cruciate ligament.

The standard textbooks of anatomy describe the ligament of Wrisberg and place it behind the posterior cruciate ligament, but do not mention the possibility of its being anterior to the posterior cruciate ligament. Grant states: "It is a matter of interest and significance that the posterior end of the lateral semilunar is attached to the femur by an oblique band that passes either in front of (lig. of Humphry) or behind (lig. of Wrisberg) the posterior cruciate ligament."

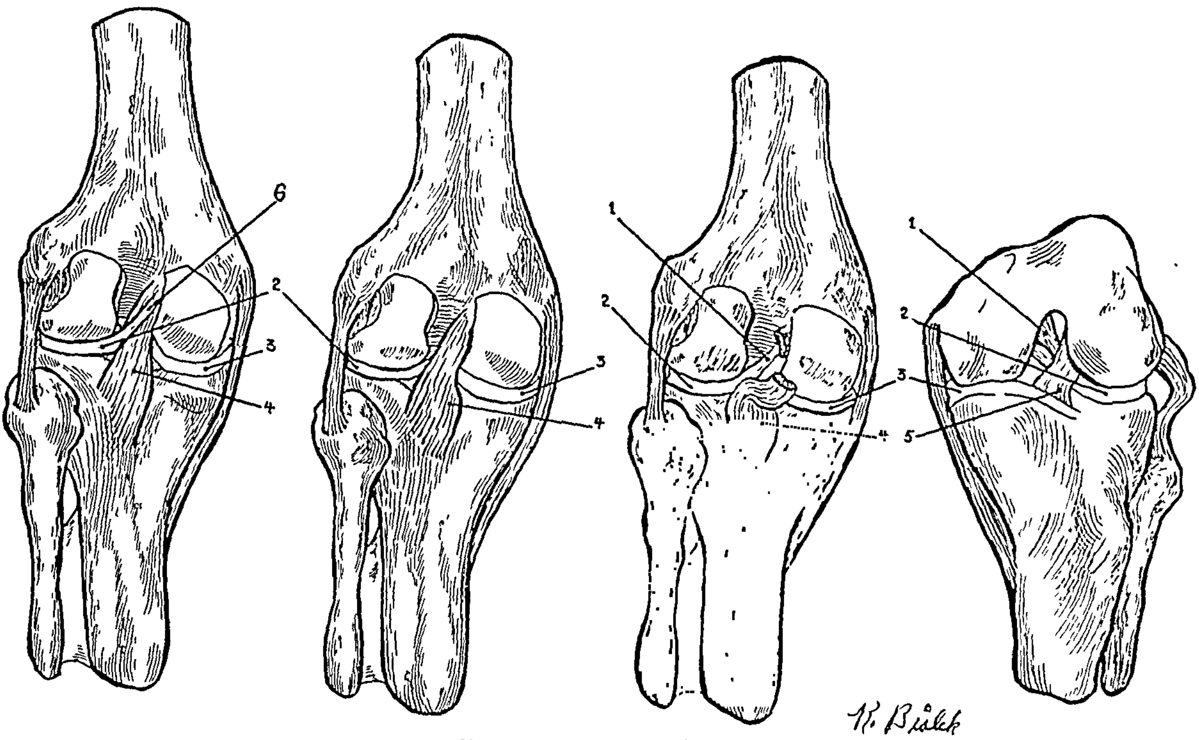

Fig. 1-A Fig. 1-B Fig. 1-C Fig. 1-D

1. Ligament of Humphry.
2. Lateral meniscus.
3. Medial meniscus.
4. Posterior cruciate ligament.
5. Anterior cruciate ligament.
6. Ligament of Wrisberg.

Fig. 1-A: The posterior aspect of a knee joint with its ligaments. The ligament of Wrisberg (*6*) is plainly seen and is typically illustrated.

Fig. 1-B: The ligament of Wrisberg is not present. The ligament of Humphry is present but does not show, since it is anterior to the posterior cruciate ligament (*4*) and is thus hidden from view.

Fig. 1-C: The same drawing as Fig. 1-B, but with the posterior cruciate ligament (*4*) cut and moved aside. The ligament of Humphry (*1*) is plainly seen, extending from the posterior aspect of the lateral meniscus (*2*) to the medial femoral condyle.

Fig. 1-D: A knee joint in a flexed position, viewed from the front. The synovial membrane has been removed from the cruciate ligaments. The ligament of Humphry (*1*) is plainly seen, lying on the anterior surface of the posterior cruciate ligament.

The authors found the ligament of Humphry only after very extensive dissection of the knee joint, and only then became cognizant of the writings of Humphry. The ligament of Wrisberg is behind the posterior cruciate ligament and extends from the posterior aspect of the lateral meniscus to the medial femoral condyle in an oblique upward and medial direction (Fig. 1-A). It may vary considerably in size. It is often rather intimately blended with the posterior cruciate ligament, but sometimes it is actually separated from the posterior cruciate ligament by several millimeters. Since it is the most posterior of the intra-articular ligaments, it is never covered with synovial membrane and accordingly is easily exposed to vision.

The ligament of Humphry is a fibrous fasciculus that originates from the posterior aspect of the lateral meniscus, extends obliquely medially and upward in front of the posterior cruciate ligament, and is inserted into the medial condyle of the femur (Fig. 1-C). It varies in size, as does the ligament of Wrisberg, but seems always to be in contact with the anterior aspect of the posterior cruciate ligament. It seems always to be covered with the synovial membrane that covers the cruciate ligaments, and is therefore obscured from view when the knee joint is exposed from the front (Fig. 1-D). It is hidden from view posteriorly by the posterior cruciate ligament (Fig. 1-B).

In a study of fifty anatomical specimens, a typical ligament of Wrisberg was found thirty times; a typical ligament of Humphry was found seventeen times. In three knee joints, there was a ligament both in front of and behind the posterior cruciate ligament. Two of these presented strong fibrous bands of a size equal to the usual ligaments of Wrisberg and Humphry. The third knee joint presented, in front of and behind the posterior cruciate ligament, a fasciculus considerably reduced in size. Examination of the knee joints of one cadaver revealed a typical ligament of Wrisberg in the right knee and a typical ligament of Humphry in the left knee. In this small series of fifty knee joints, a ligament extending from the posterior aspect of the lateral meniscus to the medial femoral condyle was invariably present.

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TREATMENT OF FRACTURE-DISLOCATION OF THE INTERPHALANGEAL JOINTS OF THE HAND

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AND MAJOR ARTHUR M. FARIS
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Fracture-dislocation of an interphalangeal joint in the hand results, in the absence of adequate treatment, in severe permanent disability. Reduction is difficult to maintain by conservative methods of splinting, because of pressure necrosis of the soft tissues. Treatment by open methods is unsatisfactory, because of the small size of the fragment and the proximity of the flexor and extensor tendons. Reduction and maintenance of the displacement by means of multiple skeletal traction has been employed by the authors, with excellent results. Previous reports of this method of treatment have not been found.

Fracture-dislocation of an interphalangeal joint of the hand is an uncommon injury. A total of seven cases were observed by the authors in a large general hospital over a period of one year. The usual causative mechanism is trauma to the end of the extended

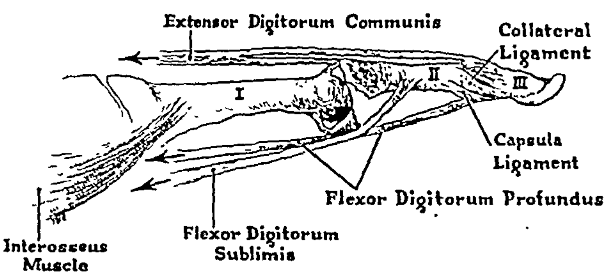

FIG. 1-A

Typical fracture-dislocation of an interphalangeal joint, showing displacements to be corrected.

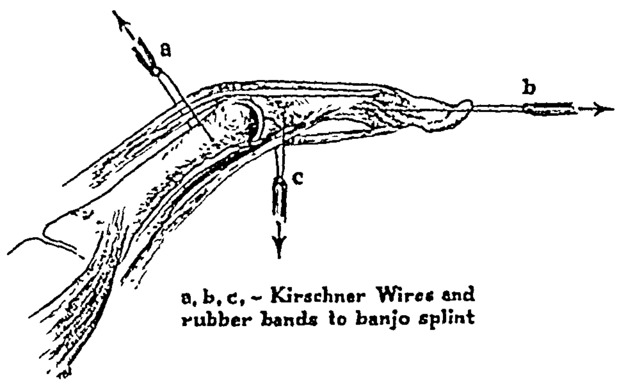

FIG. 1-B

Corrective forces applied by multiple traction.

finger. A small palmar fragment is retracted proximally by the capsular ligament, while dorsal dislocation is produced by the extensor digitorum tendon (Fig. 1). Capsular damage of varying degree is present. Deformity is immediate and marked. Accurate diagnosis can be made only by two-plane roentgenograms.

METHOD OF TREATMENT

The finger is prepared for surgery, and is covered with a sterile dressing. A plaster-of-Paris cast is applied from the proximal palmar crease high onto the forearm, and a wire banjo splint is incorporated in the desired position. Under general or local anaesthesia, a small Kirschner wire is inserted transversely through the neck of the phalanx, proximal to the dislocation; and another wire is placed transversely through the base of the phalanx, distal to the dislocation. A third wire is passed transversely through the neck of the middle phalanx, if the injury involves the proximal interphalangeal joint (Fig. 2-C). If the distal interphalangeal joint is involved, the third wire is passed transversely or vertically through the distal phalanx. In placing these wires, care must be taken to avoid the tendons and the joint capsule. A small temporary dressing is applied about each protruding wire. The wire is then cut and fashioned to form a traction bow. To each of the bows, a rubber band is attached and fixed to the banjo (Fig. 2-B). The involved joint is then flexed to from 20 to 30 degrees, and the desired traction is applied to each band at such an angle as to secure reduction of the displacement. Reduction is

TABLE I

REPORT OF CASES

Case	Diagnosis	Date and Manner of Injury	Reduction and Traction	Traction Removed	Result *
1	1 Fracture, simple, complete, chip type, anterior aspect, base of middle phalanx, left fourth finger 2 Dislocation, simple, complete, posterior, proximal interphalangeal joint, left fourth finger	Feb 2, 1944, struck on end of extended fourth finger by baseball.	Feb. 4, 1944	Mar 5, 1944	Good Flexion range 175 to 90° Motion painless, Mar. 15, 1944
2	1 Fracture, simple, complete, chip type, anterior aspect, base of middle phalanx, right fifth finger 2 Dislocation, simple, complete, posterior, proximal interphalangeal joint, right fifth finger	Mar 23, 1944, struck on end of extended fifth finger by baseball	Mar 24, 1944	Apr 21, 1944	Good Flexion range 180 to 100° Motion painless, May 1, 1944.
3	1 Fracture, simple, complete, chip type, anterior aspect, base of middle phalanx, right second finger 2 Dislocation, simple, complete, posterior, proximal interphalangeal joint, right second finger	Apr. 12, 1944, struck on end of extended second finger by baseball	Apr. 13, 1944	May 7, 1944	Good Flexion range 180 to 100° Motion painless, May 20, 1944
4	1 Fracture, simple, complete, chip type, anterior aspect, base of middle phalanx, left fourth finger 2 Dislocation, simple, complete, posterior, proximal interphalangeal joint, left fourth finger	Apr 26, 1944, struck on end of extended fourth finger by baseball	Apr 27, 1944	May 18, 1944	Good Flexion range 180 to 100° Motion painless, May 30, 1944
5	1 Fracture, simple, complete, chip type, anterior aspect, base of middle phalanx, right third finger 2 Dislocation, simple, complete, posterior, proximal interphalangeal joint, right third finger	May 26, 1944, struck on end of extended third finger by baseball	June 19, 1944	July 17, 1944	Good Flexion range 175 to 110° Motion painless, July 25, 1944
6	1 Fracture, simple, complete, chip type, anterior aspect, base of distal phalanx, left thumb 2 Dislocation, simple incomplete, posterior, distal interphalangeal joint, left thumb	May 21, 1944, struck on end of extended left thumb by baseball	June 23, 1944	July 14, 1944	Good Flexion range 180 to 110° Motion painless, July 28, 1944
7	1 Fracture, simple, complete, chip type anterior aspect, base of middle phalanx, right fifth finger. 2 Dislocation, simple, complete, posterior, proximal interphalangeal joint, right fifth finger	Sept 7, 1944, struck on end of extended fifth finger by softball	Sept 8, 1944	Sept 30, 1944	Good Flexion range 175 to 110° Motion painless, Oct 5, 1944

* Results here recorded were present upon return to duty. Rapid troop movements prevented recording final end results.

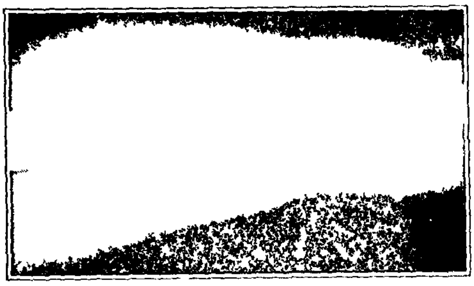

FIG. 2-A

Case No. 5, showing fracture-dislocation of proximal interphalangeal joint.

Fig. 2-A: Before reduction.

Fig. 2-B: Apparatus used in treatment.

Fig. 2-C: Reduction with traction applied.

Fig. 2-D: Final result.

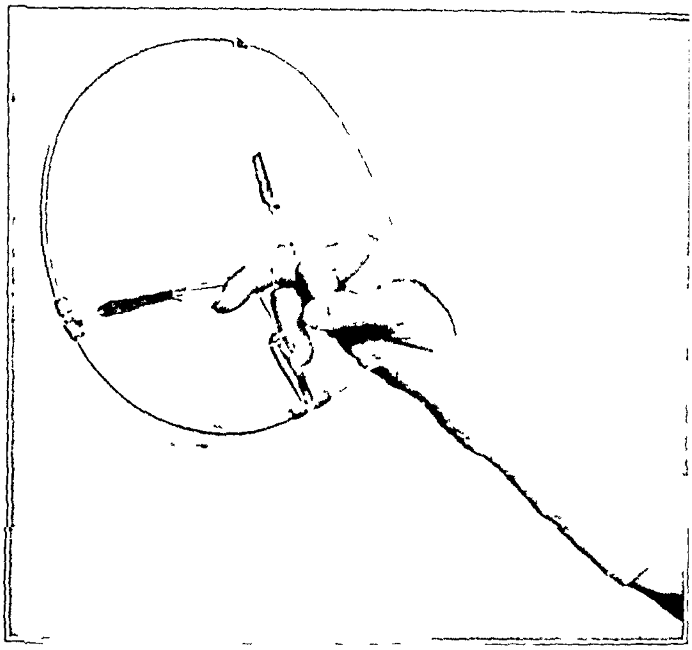

FIG. 2-B

FIG. 2-C

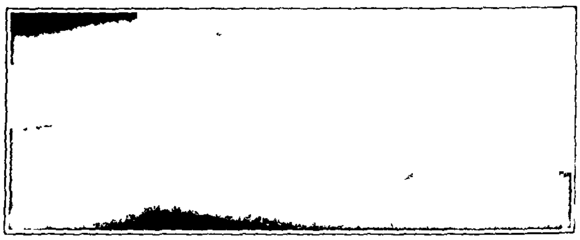

FIG. 2-D

checked by roentgenogram after a few hours, the necessary adjustments are made, and further roentgenographic observations are made, as indicated. Active motion of all joints of the uninjured fingers, and of the uninvolved joints of the injured finger, when possible is instituted immediately and is continued throughout the treatment. Traction is removed after three or four weeks and physical therapy is given. The return of function is rapid (Table I).

In the seven cases treated by the authors, reduction of the dislocation was well maintained, and bony union of the fragments was secured. The shortest period of traction-fixation was twenty-one days, and the longest was thirty days. There were no operative infections. This method of treatment gives an excellent functional result.

THE POSITION OF THE EXTERNAL HIP JOINT IN THE ABOVE-THE-KNEE PROSTHESIS WITH PELVIC SUSPENSION

An Experimental Approach to the Problem *

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Limb makers, in designing above-the-knee prostheses, are becoming more and more convinced of the value of the pelvic type of suspension. The upper end of the prosthesis is articulated, through an external joint, with a rigid pelvic band. The limb moves freely in flexion and extension through the artificial and the intact hip joints, but abduction, adduction, and rotation are largely precluded by the arrangement. The axis around which flexion and extension occur extends from the external joint to the center of the hip joint.

The position of the joint, between pelvic band and prosthesis, should be such that the distal parts of the limb are moved forward in approximately a straight line, without appreciable abduction or adduction, when the thigh is flexed. Thomas has stated that a common error is to place the joint too far posteriorly, or over the greater trochanter of the femur. This results in an awkward gait, since the prosthesis moves outward, as well as forward, when the stump is flexed.

At the suggestion of Dr. Atha Thomas, the authors have devised an experimental method for determining the optimum position—so far as straight-forward flexion of the limb is concerned—of the external joint in the above-the-knee prosthesis with pelvic suspension.

MATERIALS AND METHODS

Three cadavera, whose hip joints were anatomically normal and freely movable in flexion, extension, abduction, adduction, and external and internal rotation, were utilized in this investigation. Each was placed in the supine position on a table, and firmly anchored in place by means of lag screws, which penetrated the table top from below and were screwed into the sacro-iliac joint.

An adjustable bracket (Figs. 6, 8, 10, and 12) was attached to the table, directly opposite the left hip joint of each cadaver. The right hip joint of the third cadaver was also studied. The upper end of the bracket contained a ball-and-socket joint, through the ball of which passed a snugly fitted brass rod. One end of the rod was sharpened and threaded for a short distance behind the point. The rod, when passed through the ball-and-socket joint and driven into the head of the femur, served as a fixed axis, around which passive flexion of the thigh could be carried out. The bracket was so constructed that the ball-and-socket joint could be moved anteriorly, posteriorly, rostrally, and caudally with relation to the hip joint; it was thus possible to simulate all possible positions of the external joint in the above-the-knee prosthesis with pelvic suspension and to determine which positions were most conducive to straight-forward flexion.

All soft tissues were left in place in the first cadaver studied. The sharpened end of the rod was driven through the soft tissues into the head of the femur (Figs. 4-A, 4-B, 5-A, and 5-B), where its position was checked, when considered necessary, by anteroposterior and lateral roentgenograms, taken with a portable roentgenographic unit. The capsule of the hip joint, and the neck and proximal part of the shaft of the femur, were exposed in each of the other two cadavera by removing the overlying tissues (Figs. 12 and 13).

Measurements were made to determine the relationship of the rod—at a point tan-

* Presented before the Rocky Mountain Section of the Society for Experimental Biology and Medicine, December 7, 1945.

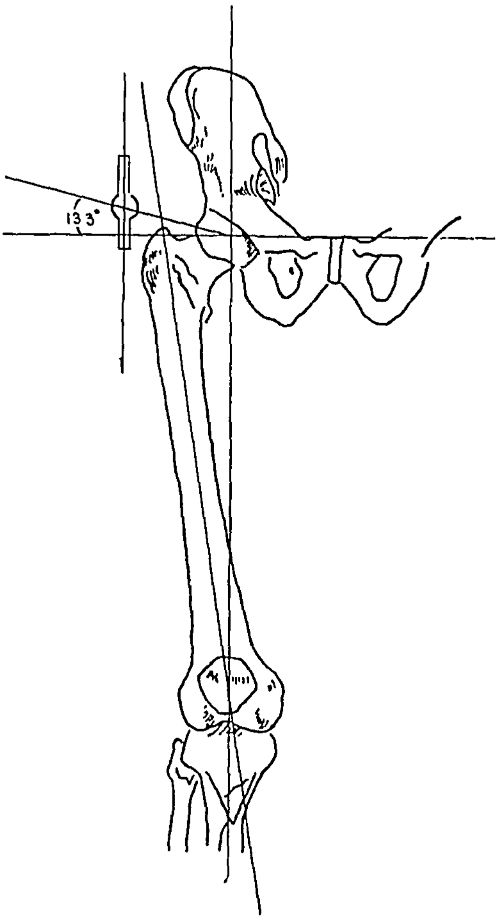

FIG. 1

The relation of the axis of rotation to the transverse acetabular plane in Position 1a. The relation of the axis to the greater trochanter is not accurately shown.

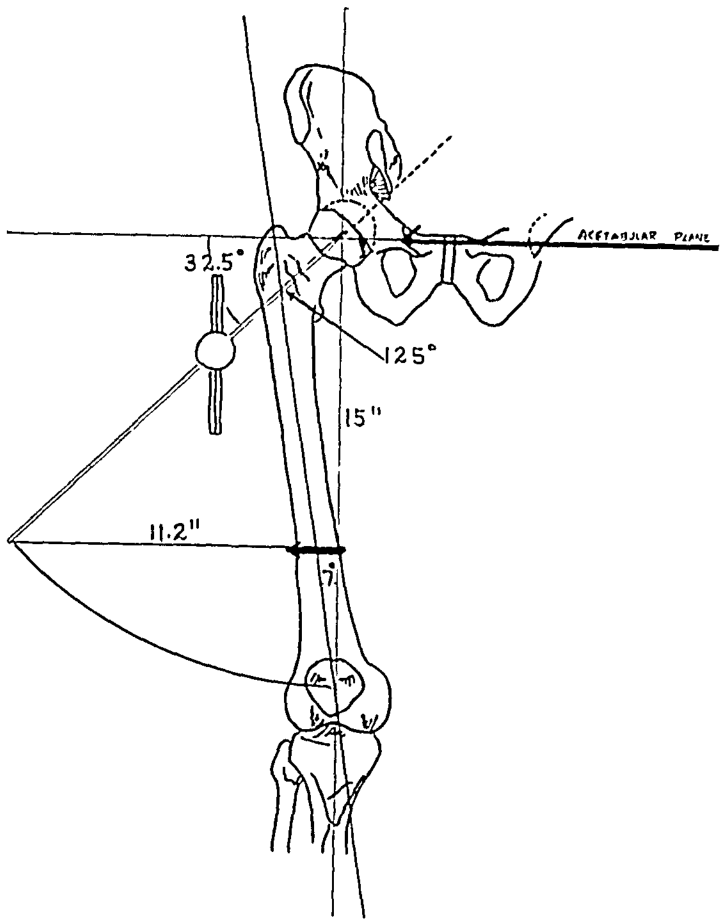

FIG. 3

The relation of the axis of rotation to the transverse acetabular plane in Position 3a. The drawing demonstrates that the axis of rotation does not shift during flexion to 54 degrees. The lateral displacement of the femur, if flexion were carried to 90 degrees around this axis, was calculated and found to be 11.2 inches. The lateral displacement which occurred at flexion of 54 degrees was six and one-quarter inches (Table I). The latter figure correlated in direct proportion with that calculated for theoretical flexion of 90 degrees, thus proving that the axis of rotation remains fixed in any desired position, so far as our experimental method is concerned.

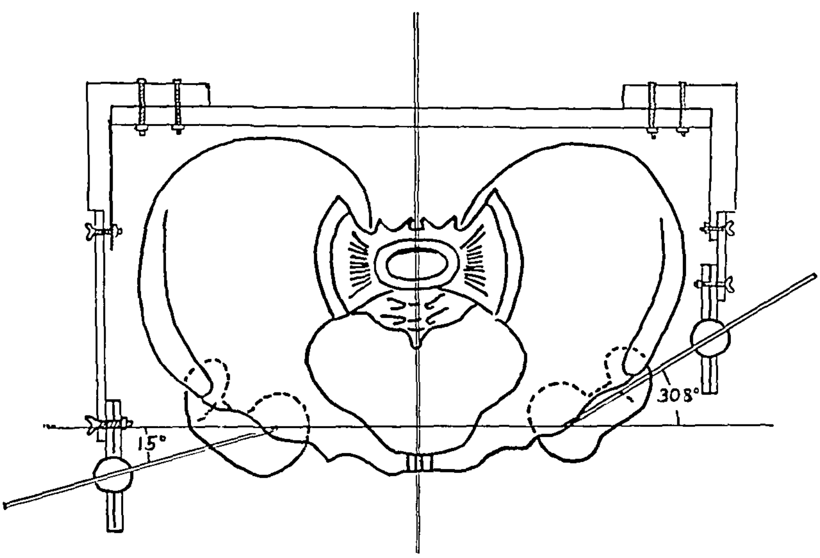

FIG. 2

The relation of the axes of rotation to the frontal plane of the pelvis in Position 1a (left) and Position 3a (right).

gent to the lateral surface of the thigh—to the frontal plane of the anterior superior iliac spines, to the transverse plane of the spines, and to the planes of the anterior and superior borders of the greater trochanter of the femur. The angles formed between the rod and the frontal and transverse planes of the anterior superior iliac spines were determined, as illustrated in Figures 1, 2, and 3. The degrees of rotation, abduction, and flexion of the thigh were also measured and recorded (Table I).

The deviation of the distal end of the femur (in abduction or adduction), with re-

TABLE I

RESULTS OF EXPERIMENTS

Position No.	Position of External Joint (Hip Joint of Prosthesis) Relative to				Angle † of Axis Rod with		Starting Position of Thigh					Deviation of Femoral Condyles at 54° Flexion (*Inches*)	Relation of Position of Thigh at 54° Flexion to Anatomical Position (*Inches*)
	Greater Trochanter *		Frontal ** Plane (*Inches*)	Transverse ** Plane (*Inches*)	Frontal Plane (*Degrees*)	Transverse Plane (*Degrees*)	Flexion		Abduction		External Rotation (*Degrees*)		
	Ant. Border (*Inches*)	Upper Border (*Inches*)					(*Inches*)	(*Degrees*)	(*Inches*)	(*Degrees*)			
1a	1	−¼	2½	2	15.0	13.3	0		0		47.0	Abd. ¾	
2a	−½	0	4	1¾	−19.3	19.0	0		0		47.0	Abd. 3¼	
3a	−¼	−1½	4½	4	−30.8	−32.5	0		0		67.2	Abd. 6¼	
4a	−¼	−1½	2	4	26.4	−32.5	0		0		11.0	Abd. ½	
5a	−¼	−1½	2¾	4	9.3	−32.5	0		0		27.0	Abd. 2¼	
6a	−¼	−1½	3	4	3.6	−32.5	0		0		32.8	Abd. 4½	
1b	1	¼	2½	2	−10.8	16.9	0		2½	8.0	65.0	Add. 4⅜	Add. 1⅞
2b	1½	−⅜	2¼	2	−5.1	16.9	0		3½	11.2	78.0	Add. 1¼	Abd. 2¼
3b	2	−½	1¼	2¾	17.8	−0.3	0		2½	8.0	59.0	Add. 3¾	Add. 1¼
4b	1⅜	0	2	2	0.7	16.9		23.0	4	12.8	45.0	Add. 3	Abd. 1
5b	0	−1	3⅛	3	−25.0	−6.0		23.0	4½	14.4	46.0	Abd. 1½	Abd. 6
1c	−½	−¼	3	2½	−27.9	5.0	3.0	10.5	4	14.0	50.0	Abd. 2¼	Abd. 6¼
2c	½	−¼	2	2½	−5.0	5.0	3.0	10.5	4	14.0	50.0	0	Abd. 4
3c	¾	0	1¾	2¼	0.7	10.7	3.0	10.5	4	14.0	50.0	Add. 1⅜	Abd. 2⅝
4c	1½	0	1	2¼	17.9	10.7	3.0	10.5	4	14.0	50.0	Add. 2⅛	Abd. 1⅞
5c	2¼	−¼	¼	2½	35.0	5.0	3.0	10.5	4	14.0	50.0	Add. 3⅛	Abd. ⅞
1d	¾	0	2¼	2¾	0	0	0		0		30.0	Add. 1¼	Add. 1¼
2d	¾	−⅛	2¼	2¾	0	0	0		2	7.0	30.0	Add. 2⅜	Add. ⅜
3d	¾	−¼	2¼	2¾	0	0	0		4	14.0	30.0	Add. 2⅜	Abd. 1⅝
4d	¾	−⅛	2¼	2¾	0	0	4.0	14.0	2	7.0	30.0	Add. ⅞	Abd. 1⅛
5d	¾	−¼	2¼	2¾	0	0	4.0	14.0	4	14.0	30.0	Add. ¾	Abd. 3¼
6d	⅞	−¼	2¼	2¾	0	0	4.0	14.0	4	14.0	45.0	Add. 1¾	Abd. 2¼
7d	¾	−¼	2½	2¾	−7.0	0	4.0	14.0	4	14.0	45.0	Add. ⅜	Abd. 3⅝

† Angles preceded by minus signs are posterior to frontal plane or inferior to transverse plane; others are anterior or superior.
* Minus sign signifies posterior or inferior; no prefix, anterior or superior.
** Through anterior superior iliac spines.

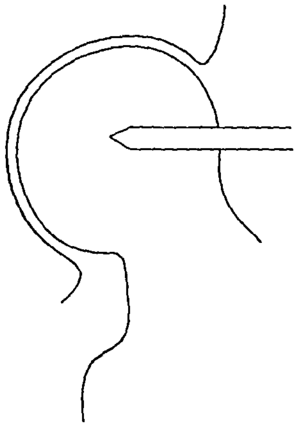

FIG. 4-A

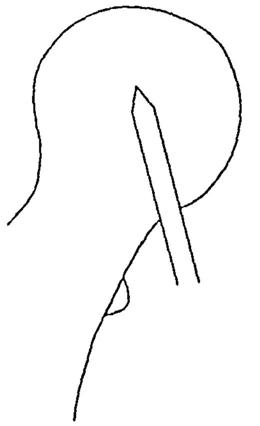

FIG. 4-B

Tracings of lateral and anteroposterior roentgenograms, showing the relation of the rod to the head of the femur in Position 1a.

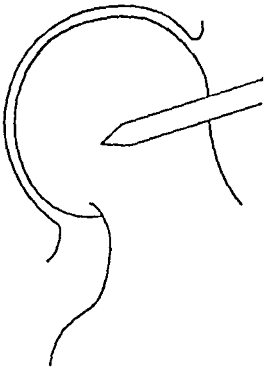

FIG. 5-A

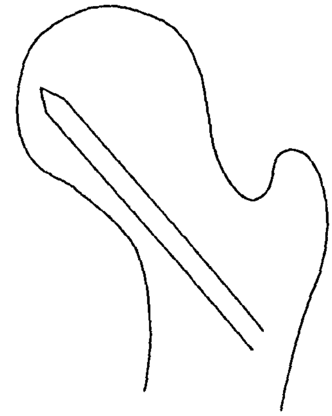

FIG. 5-B

Tracings of lateral and anteroposterior roentgenograms, showing the relation of the rod to the head of the femur in Position 2a. Because of the difficult conditions under which the roentgenograms were obtained, they could not be reproduced successfully.

lation to its starting and anatomical positions, was measured after flexion of the thigh to 54 degrees from each of twenty-three starting positions (Table I). Flexion was maintained, while measurements and photographs were taken, by means of a rod extending between the popliteal area of the thigh and the table; the rod was sharp at its point of contact with the table and did not influence the position of the limb as to lateral or medial deviation.

RESULTS

Six positions of the rod, as inserted through the ball-and-socket joint into the head of the femur, were studied in the first cadaver. A description of each position is presented in Table I; in none of the starting positions was there either flexion or abduction of the thigh. External rotation varied from 11 degrees, in Position 4a, to 67.2 degrees, in Position 3a.

The location of the ball-and-socket joint in Position 1a (Fig. 6) corresponded, as nearly as could be determined, to the location of the external joint in the illustrations of the pelvic-suspension type of prosthesis, published by Thomas. The point of the rod was well centered in the head of the femur, as shown by anteroposterior and lateral roentgenograms (Figs. 4-A and 4-B). External rotation, as measured at the condyles of the femur, amounted to 47 degrees. When the thigh was flexed 54 degrees, the medial condyle of the femur was found to have deviated laterally only three-quarters of an inch (Fig. 7).

The same degree of external rotation of the femur was present in the second position studied (Table I, Position 2a), but the rod was one-half inch posterior to the plane of the anterior border of the greater trochanter, and at the level of its upper border. This position represented an attempt to simulate placing the joint of the prosthesis over the greater trochanter, which has been done frequently, according to Thomas. The position of the pin in the head of the femur is shown in Figure 5. At the end point of flexion to 54 degrees around this axis, the medial condyle had moved laterally three and one-quarter inches from its original neutral position (Figs. 8 and 9).

The rod was next driven into the head of the femur through its neck. It entered the femur one-quarter inch posterior to the plane of the anterior border of the greater trochanter, and one and one-half inches inferior to its upper border (Fig. 10). This relationship of the rod to the femur was maintained in each of the next four experiments (Positions 3a, 4a, 5a, and 6a), while the degree of external rotation was varied from 67.2 degrees to 11 degrees.

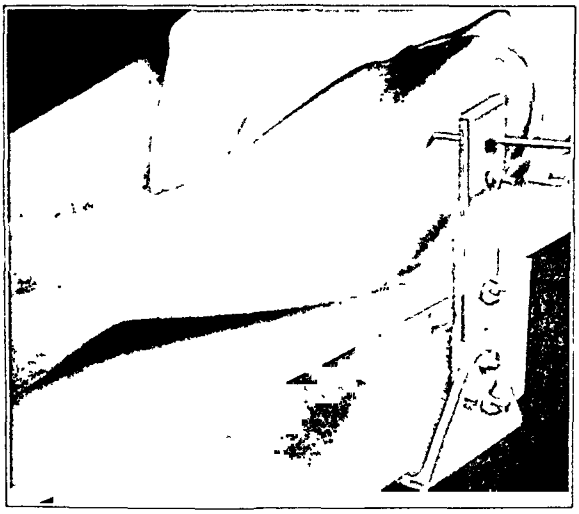

Fig. 6

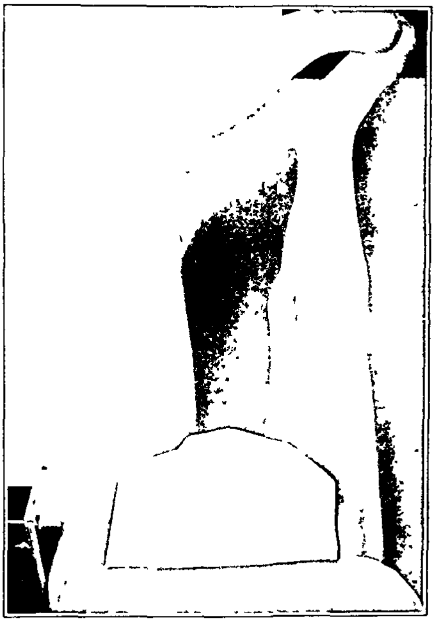

Fig. 7

Fig. 6. Position 1a prior to flexion.

Fig. 7. The position of the left thigh when flexion of 54 degrees had been produced from Position 1a. The angle from which the photograph was taken accentuates the actual degree of abduction, which measured three-quarters of an inch. The external rotation of 47 degrees is indicated by the positions of the leg and foot.

The femur was externally rotated 67.2 degrees in Position 3a. At the end of 54 degrees of flexion, the medial condyle of the femur was abducted six and one-quarter inches from its original neutral position (Figs. 10 and 11). External rotation was reduced to 11 degrees in Position 4a, and abduction at 54 degrees of flexion amounted to only one-half inch. In Position 5a, external rotation measured 27 degrees; abduction at 54 degrees of flexion measured two and one-quarter inches. When external rotation was increased to 32.8 degrees (Position 6a), abduction in flexion increased to four and one-half inches.

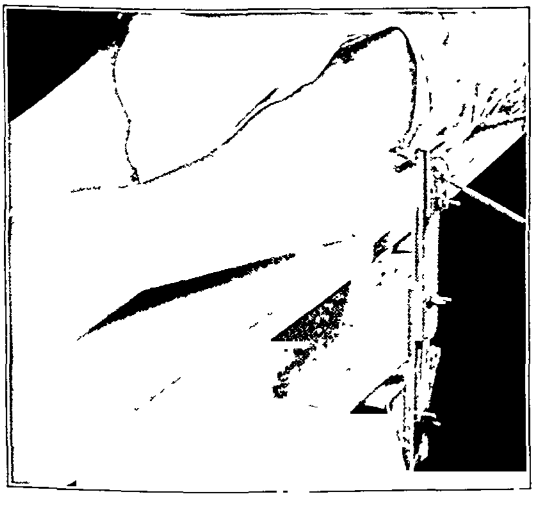

Fig. 8

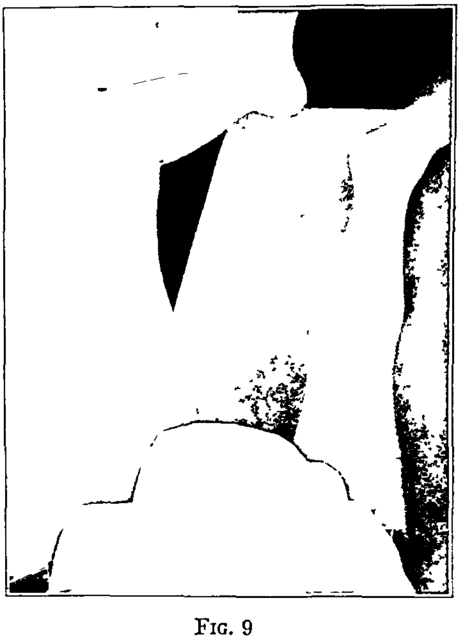

Fig. 9

Fig. 8. Position 2a prior to flexion.

Fig. 9. Abduction of three and one-quarter inches, which occurred with flexion of 54 degrees from Position 2a.

In the second cadaver, flexion was first investigated from an originally abducted position of the thigh. Before driving the rod into the head of the femur in Position 1b, the thigh was abducted 8 degrees (two and one-half inches at the medial condyle), and externally rotated 65 degrees. The relationship of the rod to the frontal and transverse planes of the anterior superior iliac spines was the same as in Position 1a. Flexion of 54 degrees resulted in adduction from the starting position of four and three-eighths inches; thus the medial condyle was actually adducted one and seven-eighths inches beyond its anatomical position.

Beginning abduction was increased to 11.2 degrees (three and one-half inches at the medial condyle) in Position 2b, before the rod was inserted into the head of the femur. The position of the rod with relation to the frontal and transverse planes of the anterior superior iliac spines remained approximately the same as in Position 1b, but external rotation was increased to 78 degrees. Flexion of 54 degrees was accompanied by adduction from the starting position of only one and one-quarter inches. The thigh therefore remained in an abducted position (two and one-quarter inches) at the end point.

Abduction in Position 3b was 8 degrees, or the same as in Position 1b; external rotation was somewhat less (59 degrees). The external joint was moved anteriorly one and one-quarter inches, and inferiorly three-quarters of an inch. At the end point there had occurred adduction of four and three-quarters inches; this carried the medial condyle to a point one and one-quarter inches medial to its anatomical position.

In order to simulate the flexed position of the stump often seen after amputations of the upper thigh, the femur, in Position 4b, was flexed 23 degrees before the rod was driven into its head. The angle between the rod and the transverse plane of the iliac spines was the same as in Positions 1b and 2b; that between the rod and the frontal plane was practically zero (0.7 degree). External rotation amounted to 45 degrees, and abduction to 12.8 degrees (four inches). With flexion to 54 degrees, the abduction was reduced from four inches to one inch.

When the ball-and-socket joint was moved posteriorly and inferiorly, so that the rod was in the plane of the anterior border of the greater trochanter and one inch below the

Fig. 10

Position 3a prior to flexion. The inferior and posterior angles between the rod and the transverse and frontal planes of the pelvis are shown.

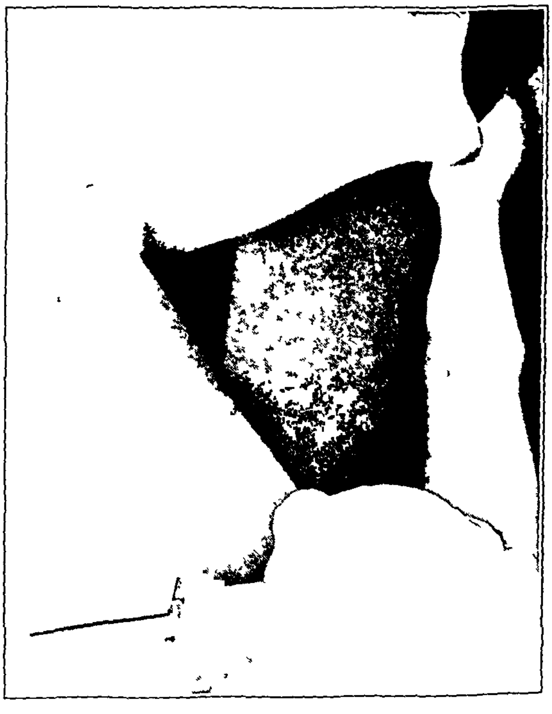

Fig. 11

Fig. 11: Abduction of six and one-quarter inches, as it occurred in flexion from Position 3a.

plane of its superior border (Position 5b), with abduction, external rotation, and flexion approximately the same as in Position 4b, flexion of 54 degrees resulted in exaggeration of the original abduction (from four and one-half to six inches).

In the investigation of the left hip of the third cadaver, it was felt that an attempt should be made to eliminate some of the numerous variables allowed in the previous experiments. Flexion, abduction, and external rotation of the thigh, in each starting position, were therefore kept constant at 10.5 degrees, 14 degrees, and 50 degrees, respectively; the relation of the rod to the transverse plane was varied only slightly. Thus the only actual variable was the angle between the rod and the frontal plane; this varied from a posterior angle of 27.9 degrees in Position 1c to an anterior angle of 35 degrees in Position 5c. In Position 1c, the original abduction of four inches was increased to six and one-quarter inches. When the posterior angle between the rod and the frontal plane was reduced to 5 degrees (Position 2c), the thigh moved straight forward; abduction at the start and at the end point (54 degrees of flexion) was four inches, or 14 degrees.

When the posterior angle was changed to an anterior angle, and then increased in size (Positions 3c, 4c, and 5c), adduction occurred in increasing amounts when the thigh was flexed. The adduction ranged from one and three-eighths inches, with an anterior angle of 0.7 degree, to three and one-eighth inches when the angle was increased to 35 degrees.

In the final experiment, utilizing the right hip joint of the third cadaver, the rod was kept parallel to the transverse and frontal planes of the anterior superior iliac spines throughout the first six positions (Positions 1d through 6d), while various combinations of external rotation, abduction, and flexion of the thigh were investigated.

When the thigh was externally rotated 30 degrees, without accompanying abduction or flexion, adduction of one and one-quarter inches occurred when it was flexed through the usual range of 54 degrees. The adduction was increased to two and three-eighths inches, when external rotation of 30 degrees at the start was accompanied by abduction of either 7 degrees or 14 degrees (Positions 2d and 3d).

Flexion of 14 degrees, combined with external rotation of 30 degrees and abduction of 7 degrees—simulating the position of the amputation stump—resulted in adduction of

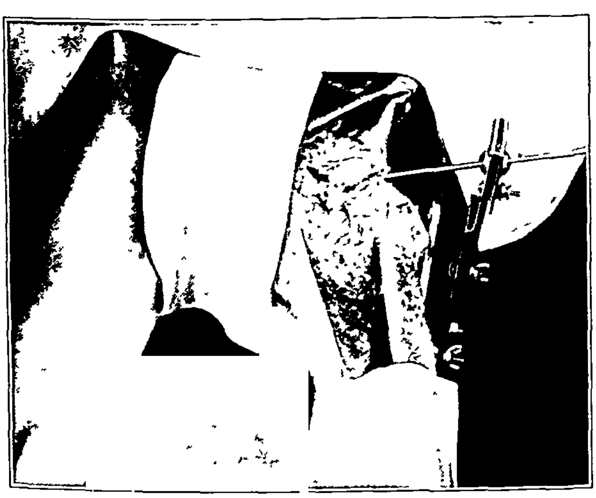

FIG. 12

Position 4b prior to flexion to 54 degrees. The thigh was flexed and abducted before the rod was driven into the head of the femur.

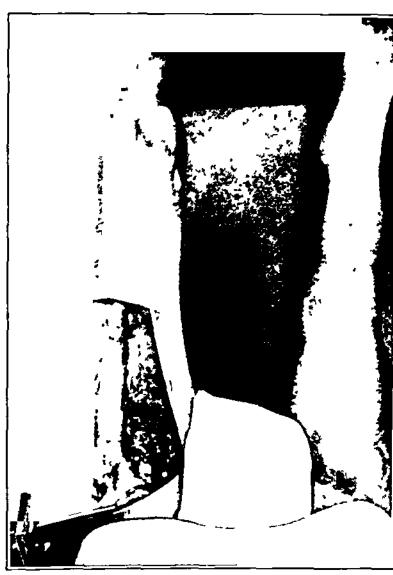

FIG. 13

Fig. 13: Flexion to 54 degrees from Position 4b. Abduction was reduced from four inches, at the start, to one inch, at the end point.

only seven-eighths of an inch (Position 4d). The amount of adduction was practically unchanged when starting abduction was increased to 14 degrees, without changing flexion and external rotation (5d); this was consistent with the results in Positions 2d and 3d, where doubling the amount of abduction, without other changes, failed to alter the amount of deviation of the thigh at flexion of 54 degrees.

Flexion and abduction were the same in Position 6d as in Position 5d, but external rotation was increased from 30 degrees to 45 degrees; adduction at 54 degrees of flexion increased from three-quarters of an inch to one and three-quarters inches, as compared with the former position.

The relationship of the rod to the frontal plane was altered in Position 7d, while flexion, abduction, and external rotation of the limb were the same as in Position 6d; the parallel relationship between the rod and the transverse plane was maintained. A posterior angle of only 7 degrees between the frontal plane and the rod was sufficient to reduce adduction from one and three-quarters inches (Position 6d) to only three-eighths of an inch.

DISCUSSION

It is obviously impossible to draw definite conclusions as to the optimum position of the external joint, with reference to the trochanter and the various planes of the pelvis, which will be applicable to the fitting of above-the-knee prostheses to any and all amputation stumps. Our studies indicate that each of the innumerable combinations of flexion, abduction, and external rotation which are likely to exist in such stumps, and to which the sockets of the prostheses must be accommodated, will probably necessitate adjustments, of greater or lesser degree, in the location of the joint. The results of the present investigation appear to support the thesis that the joint should be placed considerably anterior to the greater trochanter, as stated by Thomas.

Regarding the position of the stump following thigh amputations, Langdale-Kelham stated that one could expect to find "any variation from a long femur stump with little flexion and no abduction, to a short femur stump markedly flexed 40 degrees or more, markedly abducted, and externally rotated". The muscular forces responsible for such postural deviations of the stump are not easily accounted for.

Steindler, in analyzing the dynamics of the muscles concerned with movements of the hip joint, found that flexion and abduction of the hip nullified the external rotary action of the posterior fibers of the gluteus medius, and that almost all the fibers of the gluteus minimus rotate inward in all positions of the hip joint. He considered the rotary power of the tensor fasciae latae, and that of the hamstring muscles, to be negligible. Both piriformis and obturator internis lose some of their external rotary power when the hip is flexed, according to Steindler, and the adductor magnus is a very weak internal rotator of the hip. The gracilis was considered to be an internal rotator of the "leg" in most positions. This analysis by Steindler does not furnish an anatomicophysiological basis for the marked external rotation observed in femoral stumps.

The abduction described by Langdale-Kelham as existing in short femoral stumps is, no doubt, explained by the loss of action of the adductor longus and adductor magnus. Flexion (and possibly some external rotation) is produced by the relatively unopposed action of the iliopsoas. The lack of opposition is mainly due to the loss of the normal extensor effects of the hamstring muscles. The marked decrease in weight of the stump, as compared with that of the normal extremity, is no doubt a contributing factor to the overactivity of the iliopsoas. The weight of the artificial limb should correct both flexion and abduction of the stump, to some extent.

Regardless of inability to explain the postural deviations which are seen in the stump following thigh amputations, they must be considered in determining the most favorable position of the external joint. Positions 1c, 2c, and 3c indicate that placing the external

joint one-half inch anterior to the greater trochanter (Position 2c) results in straight-forward flexion, as compared with flexion complicated by considerable abduction when the external joint is placed over the trochanter (1c), and by adduction when it is placed three-quarters of an inch anterior to the trochanter (3c).

Thomas's opinion, that good function in artificial limbs is not promoted by placing the external joint over the greater trochanter, seems justified in the light of the results obtained in these experiments when the external joint was placed in, or posterior to, the plane of the anterior border of the trochanter. Positions 2a, 3a, 4a, 5a, 5b, and 1c are illustrative of the type of flexion that may be expected from such a posterior placement of the joint. Abduction occurred in flexion from all of these positions, in spite of considerable variation in degrees of external rotation, abduction, and flexion at the start of the respective experiments. It is interesting that the amount of abduction was very slight (one-half inch) in Position 4a, in which external rotation was only 11 degrees; this indicates that the joint might be favorably placed over the greater trochanter, if a stump with this slight degree of external rotation should be found.

The external joint may also be placed too far anteriorly, as illustrated by Positions 3c, 4c, and 5c. Flexion, abduction, and external rotation of the thigh were kept constant in these three experiments, while the external joint was in planes three-quarters of an inch, one and one-half inches, and two and one-quarter inches anterior to the anterior border of the trochanter. With each increase in the distance between the axis of rotation and the trochanter, the adduction accompanying flexion of 54 degrees increased (one and three-eighths inches, two and one-eighth inches, and three and one-eighth inches, respectively).

Our most satisfactory results, from the standpoint of straight-forward flexion, were obtained from Positions 1a, 2c, and 7d. In the first of these, with the thigh in 47 degrees of external rotation, the rod was so placed that it made an angle of 15 degrees with the frontal plane of the anterior superior iliac spines, and an angle of 13.3 degrees with the transverse plane. It was one inch anterior to the anterior border of the greater trochanter, or approximately one and three-quarters inches anterior to its lateral mid-line.

In Position 2c, external rotation amounted to 50 degrees, and the thigh was abducted 14 degrees and flexed 10.5 degrees. There was a posterior angle of 5 degrees between the rod and the frontal plane, and the angle between the rod and the transverse plane was also 5 degrees. The distance from the middle of the trochanter to the rod was one and one-quarter inches.

External rotation in Position 7d amounted to 45 degrees, and flexion and abduction to 14 degrees each. The posterior angle between the rod and the frontal plane measured 7 degrees, and the rod was parallel to the transverse plane. The distance anterior to the anterior border of the trochanter was three-quarters of an inch; it was therefore one and one-half inches from the middle of the trochanter to the rod.

In the optimum positions of the external joint, as determined by our method of investigation, the distance anterior to the middle of the trochanter varied from one and one-quarter to one and three-quarters inches. In all of these favorable positions, the rod passed one-quarter inch inferior to the plane of the superior border of the trochanter. The angles between the axis rotation and the frontal and transverse planes of the anterior superior iliac spines did not exceed 15 degrees, and they tended to approach zero.

SUMMARY

Three human cadavera were utilized for the study of the effects of varying axes of rotation upon flexion of the thigh. The investigation was carried out in an attempt to determine the optimum functional position of the external hip joint in the above-the-knee prosthesis with pelvic suspension. Variations in the angles formed between the axes of rotation and the frontal and transverse planes of the anterior superior iliac spines were fa-

cilitated by an adjustable ball-and-socket joint; this was placed opposite the hip joint of the cadaver, and a rod was passed through it into the center of the head of the femur.

Flexion to 54 degrees was carried out from starting positions—characterized by various combinations of flexion, abduction, and external rotation of the thigh—which simulated the postural deviations observed clinically in amputation stumps.

The results indicate that, for straight-forward flexion to occur, the external joint should be placed from one and one-quarter to one and three-quarters inches anterior to the middle of the greater trochanter.

An axis which passed through the greater trochanter was conducive to considerable abduction, as the thigh was moved forward in flexion. Conversely, when the external joint was placed too far anteriorly, adduction was associated with flexion.

Considerable adjustment in the position of the external joint, within rather narrow limits, is necessary to compensate for varying degrees of flexion, abduction, and external rotation of the thigh.

NOTE: The authors wish to express their sincere appreciation to Dr. Atha Thomas for suggesting this investigation, and for constructive criticism of the work as it was carried out. Mr. Chester C. Haddan, President of the Association of Limb Manufacturers of America, has also given helpful suggestions and criticism. Thanks are due Mr. Glenn Mills for the excellent photographs, illustrating the methods and results of the experimental procedures. Miss Helen Veltric of the Department of Roentgenology, University of Colorado Medical School, and Dr. Joseph McGill, were most cooperative in preparing the roentgenograms. The retouching of the illustrations was made possible by a grant from the Council on Research, University of Colorado Graduate School.

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MUTATIONAL DYSOSTOSIS (CLEIDOCRANIAL DYSOSTOSIS)

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Mutational dysostosis is a condition, frequently transmitted by parents to offspring, which is characterized by multiple, variable developmental skeletal anomalies. The more prominent and frequent of these anomalies are aplasia of the clavicles, delay in closure of fontanelles and cranial sutures, brachycephalia, prognathism, irregularities in dentition, and structural abnormalities in the skull bones, vertebrae, sacrum, pelvis, femora, scapulae, metacarpals, metatarsals, and phalanges.

Although Morand is usually credited with the earliest description of the disease, the case cited by him in 1766 was, according to Fitchet, definitely not one of mutational dysostosis. Terry states that, in 1760, Meckel reported an infant born without clavicles. In 1765, Martin reported the case of a man, thirty years old, one of whose clavicles was deficient posteriorly; the man's father, grandfather, and one uncle had abnormally mobile shoulders, and presumably abnormal clavicles.

The first authentic case to be reported in the English literature appears in the 1870 edition of the Descriptive Catalogue of the Warren Anatomical Museum of Harvard University as a contribution of Dr. Ephraim Cutter of Woburn, Massachusetts. The case was that of an eleven-year-old girl, who died of acute disease and whose imperfectly developed clavicle was presented to the Museum in 1868 with the notation that the other clavicle was similarly affected. The clavicle was one and three-quarters inches in length and about one-third of an inch in width, and was flattened and moderately curved. There was the usual attachment to the sternum but none to the scapula. The father of the child, who was exhibited to the Society for Medical Improvement by Dr. Cutter, had defects in both clavicles, but the outer half of each bone was indistinctly felt in connection with the scapula. The father stated that two of his brothers had the same malformation, and he thought that his father, from the slope of his shoulders, may have had the same defect. The girl had seven brothers and one sister; all of the boys had the malformation on one or both sides.

The first detailed description of the disease as a pathological entity was made by Marie and Sainton, who reported four cases, occurring in a mother and daughter in one family and in a father and son in another family. Marie and Sainton named the disease "*la dysostose cléido-cranienne héréditaire*", and stated that the cardinal features of the syndrome were: (1) a varying degree of aplasia of the clavicles; (2) overdevelopment of the transverse diameter of the cranium coincident with delay in ossification of the fontanelles; and (3) hereditary transmission.

The term "cleidocranial dysostosis" was applied to this affection by all writers until 1936, when Rhinehart called attention to its mutational character and to the variety and inconstancy of findings, and proposed the name "mutational dysostosis" as more rational and descriptive.

In 1929, Fitchet made an exhaustive survey of available literature on the subject, and abstracted all cases reported prior to that time. In this survey, 151 cases were collected, of which eighty-eight were familial, occurring in twenty-four different families, and sixty-three were either isolated or were without history of relationship to other persons having the disease.

In 1937, Engel collected a total of 228 cases reported in the literature, of which 106 were familial, occurring in twenty-five families, and 122 were sporadic.

The author has made a survey of all case reports and articles on mutational or cleidocranial dysostosis published from January 1929 through March 1944, as reported in the Quarterly Cumulative Index Medicus. These articles are listed in the bibliography. Six

additional cases are reported here. As a result of this survey, 172 cases have been added to those reported by Fitchet, of which 110 were familial, occurring in twenty-eight different families, and sixty-two were sporadic or without family history of the disease. Seventy-one were males, seventy-nine were females, and the sex of the remaining twenty-two was not reported. The surveys of Fitchet and the author give a total of 323 reported cases, of which 198 were familial, occurring in fifty-two families, and 125 were sporadic or isolated. Of these, approximately half were males.

The apparent rarity of the condition is indicated by the scarcity of published reports and anatomical specimens. Kinsella stated that in the museums of the world there were only nine skulls and two complete skeletons showing the condition; five of the skulls and both skeletons were in the Institute of Pathological Anatomy of the University of Vienna.

The geographic distribution has been interesting. Cases have been reported from every continent; the central European countries, England, and the United States have contributed the largest numbers.

While the majority of the cases cited have been of the familial type, examples of apparently sporadic occurrence are not at all uncommon. In many instances the histories

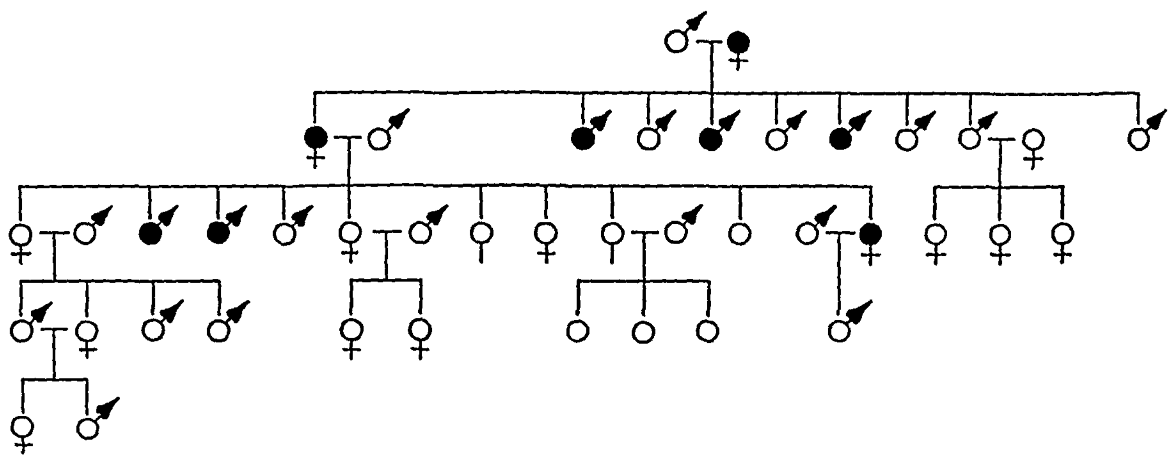

CHART I
Family reported by Carrière, Huriez, and Décamps.

have not been sufficiently detailed to rule out the occurrence of anomalies in other members of the families, and the relatives of many of these patients have not been examined carefully for signs of the disease.

In those cases showing a hereditary background, transmission has been by both male and female members of the family to a nearly equal degree. In the entire series of cases, the disease was known to have been transmitted by thirty males and thirty-two females. In many instances, the disease has appeared in two successive generations and has been lost in the following generation. In eight families, the disease appeared in three successive generations; in four families, it appeared in four successive generations; in one family, it appeared in five successive generations. No authentic instance could be found where the disease appeared in one generation, skipped one or more generations, and then reappeared in a subsequent generation. In the family studied by Langmead and by Carpenter, as reported by Fitchet, two affected children were born to parents who were said to have been normal; the parents were not examined, and discrepancies in the accounts of the family by the two authors throw discredit upon the accuracy of the study.

Examples are numerous of families in which the disease disappeared, not to reappear in subsequent generations. In the family reported by Carrière, Huriez, and Décamps, the disease appeared in eight individuals in three successive generations; in the two subsequent generations, no cases were present in eleven individuals (Chart I). In the family reported by La Chapelle, the disease appeared in at least eight members of three generations (Chart II). A normal woman of the second generation (whose mother and five of

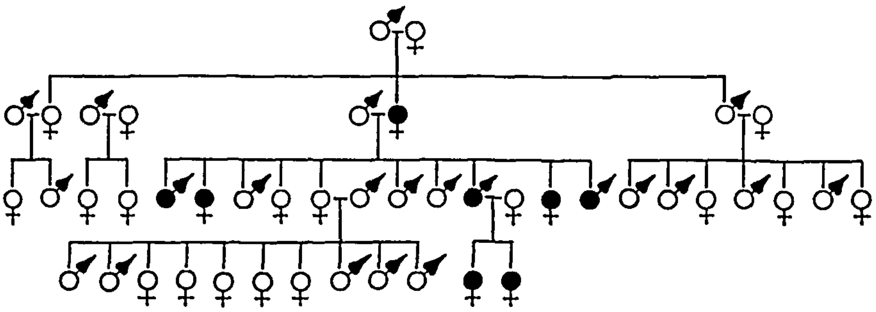

CHART II
Family reported by La Chapelle.

whose brothers and sisters had the disease) bore ten normal children. In the family reported by Burkens, La Chapelle, and Groen, the disease appeared in four generations; in the third generation, five out of thirteen individuals showed evidence of the disease; in the fourth generation, only one out of twenty-two individuals was affected (Chart III).

In families in which the disease appeared in several generations, it was transmitted to 134 individuals and not transmitted to seventy individuals. Examples are common in which four out of six, or seven out of eight children showed signs of the disease.

The etiology of the disease is unknown, but it is unquestionably associated with a defect in the parental germ plasm, as first suggested by Hultkrantz. Strauch believes that an endogenic cause operates, probably in the parental germ plasm, with defects of certain

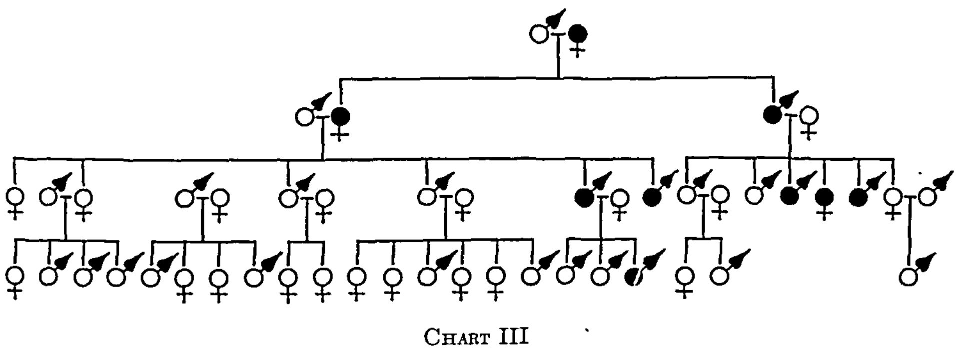

CHART III
Family reported by Burkens, La Chapelle, and Groen.

elementary building units of the chromosomes which carry the hereditary potentialities,—that is, there is a faulty *Anlage* in the system of membranous bones, the skull bones and clavicles, which is also present occasionally in the bones of chondral origin.

Another theory was advanced by Jansen, who suggested that the defects might be produced (during the eighth week of gestation) through compression of various parts of the growing foetus by a small amniotic sac. Jansen's theory fails to explain the pathogenesis of many of the conditions common to this disease,—notably the appearance of supernumerary digits in hands and feet, extra epiphyses, supernumerary teeth and vertebrae, delayed secondary dentition, and thickening of flat bones.

Greig, Fitzwilliams, and others have commented on the fact that most of the defects have been in bones formed in membrane. However, as Fitzwilliams and others have pointed out, there are many authentic examples of defects of bones or portions of bones not formed in membrane.

In his monograph on the development of the clavicle, Fawcett states that the earliest recognizable step in this process is noted in the embryo of eleven millimeters when a condensed, curved rod of connective tissue appears beneath the acromion process and the

first rib. Within this connective tissue is laid down an inner and an outer mass of precartilage; the former lies above and anterior to the latter and they are separated from one another by connective tissue. At seventeen millimeters, ossification begins in the center of each precartilaginous mass. At eighteen to nineteen millimeters, fusion occurs between the opposing ends of the two masses of precartilage, and a third center of ossification appears in the precartilaginous bridge. At twenty-seven millimeters, cartilage cells appear in the outer segment and the subsequent development of bone in this area occurs at the expense of the cartilage. Therefore, the clavicle develops in three segments,—outer, middle, and inner. In the outer and inner segments, bone is formed partially in membrane and partially in cartilage; in the middle segment, bone is formed wholly in membrane. Although knowledge of this process aids in the understanding of the embryological basis for the variations noted in the clavicular defects, it does not explain the failures of development and fusion.

Various theories have been advanced to explain the dental defects. Stocks, as quoted by Rushton, suggests that the abnormalities arise from restriction of the erupting area by the stunting of the jaws; he fails to explain the presence of supernumerary premolars and the absence of some of the molars. Fröhlich believes that all of the defects are part of the syndrome, and therefore are referable to deficiencies in the parental germ plasm.

Rushton cites Grüneberg's observations on grey-lethal mutation in the mouse, which is characterized by lack of all secondary bone absorption processes in the skeleton: The bone substance laid down in development is preserved in its entirety. The growth of the teeth is limited by the width and size of the sockets when the teeth are enclosed in them. The teeth assume peculiar shapes; some are narrow and others are compressed from above downward. Grüneberg states that the former concept of *stimulus* (pressure) leading directly to *response* (absorption) has to be revised to the concept of *stimulus* (pressure) plus an *hereditary basis for response* leading to *response* (absorption). Rushton, in commenting on Grüneberg's observations, suggests that the appearance and behavior of the teeth in mutational dysostosis may be due to a defect in the bone-absorption mechanism of the jaws.

Durante and Porak suggest that the disease may be a variant of osteogenesis imperfecta.

Rubens and several other writers report isolated cases of cleidocranial dysostosis which also showed abnormalities characteristic of craniofacial dysostosis with ocular hypertelorism (Crouzon's disease). The typical features of hypertelorism, as noted by Rubens, are a wide separation of the orbits, a brachycephalic skull with small face and large cranium, flattening of the occiput, and bulging of the temporal regions. The nasal bridge is broad and the tip of the nose is retroussé. The eyes may show an external strabismus. Mental deficiency occurs in the more severe cases.

Tuberculosis, syphilis, other infections and intoxications, consanguinity, and rickets seem to play no part in the etiology.

CHARACTERISTICS OF THE DISEASE

Mutational dysostosis is characterized by multiple defects in development and structure; these are almost wholly confined to the skeleton, except as certain skeletal abnormalities affect muscles and other organs. Most of the defects are present at birth, but many of them, especially the cranial and dental anomalies, become manifest as the child grows and develops. Variations from the typical abnormalities are common, and no one finding is characteristic of all cases.

Skull

The skull is brachycephalic, with a cephalic index of more than 80 degrees. The biparietal diameter is increased and the fronto-occipital diameter is decreased. There is

usually marked prominence of the frontal, parietal, and occipital bosses with depression of the sagittal suture, thus giving a "hot cross bun" effect, or natiform skull. The metopic suture, which in the foetus separates the two lateral halves of the frontal bone, persists into late childhood and frequently never fuses. There is delayed and often incomplete closure of the fontanelles, with persistence of large, irregular defects in the anterior, posterior, mastoid, and sphenoid fontanelles. Sometimes the fontanelles develop heavy fascial or thin bony coverings so that pulsation of the brain cannot be felt, but there is seldom complete bony closure with tables of normal thickness. Most of the suture lines are wide, depressed, and tortuous, and include many wormian bones derived from accessory centers of ossification. Variations in the supra-orbital ridges are common; although the ridges are usually overdeveloped and prominent, defects are occasionally seen.

The base of the skull is usually kyphotic. The sphenoid bone is underdeveloped, narrow, and short. The foramen magnum is large and faces forward and downward, so that a line drawn through the sagittal plane, when continued anteriorly, passes through the nasion or glabella. Occasionally, defects are noted in the posterior wall of the foramen magnum.

The bones of the face are generally underdeveloped, small, and asymmetrical. The superior maxillae and small facial bones show the greatest number of abnormalities. The maxillae are micrognathous and irregular in outline and structure with small, depressed frontal processes; the palate is highly arched, narrow, and occasionally cleft. The nasal, lacrimal, and malar bones are partially or wholly deficient, and gaps may be present between the zygomatic processes of the temporal bones and the corresponding processes of the superior maxillae. The mandible, on the other hand, is large, long, and prognathous, with obtuse angles. The alveolar process is broad. When the mouth is closed, the occlusal surface of the mandible is well forward of the corresponding surfaces of the maxillae. The mental suture is often wide, and the genial tubercles are often so much enlarged that they project backward like bony spines. The paranasal sinuses and mastoid cells are usually small; the latter may be absent or sclerosed. Occasionally the frontal sinuses are disproportionately large.

Teeth

Dental abnormalities are common, and frequently give rise to troublesome and, at times, dangerous complications. The deciduous dentition is usually normal, although occasionally it is delayed. The permanent teeth are very slow to appear; most of them remain unerupted until late in life, and many never erupt, but lie buried in the jaw. The first molars and lower central incisors are the first to erupt; the upper central incisors frequently do not appear. The wearing of artificial dentures seems to stimulate eruption of teeth, even in elderly people, probably from absorption of the overlying bone.

The teeth that do appear are apt to be small, irregularly placed, and crowded, badly embedded, and incompletely erupted. Many of the deciduous teeth remain throughout life and lie among the permanent teeth. The crowns of the erupted permanent teeth are somewhat irregular in outline, with defects in the enamel, dentine, and cement, making them especially subject to caries, periodontoclasia, and hypertrophied gums. The roots are uneven, curved or hooked, and occasionally show spiral twisting. The crowns of the unerupted teeth are spherical or conical in shape, and show pits and elevations due to uneven deposition of enamel.

Absence of some teeth, especially of the upper incisors and molars (and occasionally of the cuspids), is common; supernumerary teeth are frequently seen. The latter, which are usually premolars as far as structure is concerned, are located most commonly in the incisor and premolar areas, and vary in number from two to fourteen.

Dentigerous cysts are often present, and are presumably due to failure of eruption, followed by proliferation and degeneration of epithelial remnants around the crowns of

the teeth. If the cysts are multiple, and in close proximity to one another, they may become confluent. Secondary infection of such cysts has been reported by Fröhlich, and is noted in this report in Case 6.

Upper Extremities

Defects in the clavicles are among the commonest lesions found in mutational dysostosis, and may vary from a small defect in one clavicle to complete absence of both bones. Usually small, bony stumps are present mesially, which articulate with the sternum and to which the sternomastoid and pectoralis major muscles are attached. Frequently both sternal and acromial ends are present, but ununited; occasionally only the acromial ends are present. In about 10 per cent. of all reported cases, the clavicles are entirely absent. In at least one case, three separate bony fragments were present on each side. If small acromial fragments are present, they may articulate with the outer portions of the acromial processes and project out over the shoulder joints. Some authors have reported the presence of fibrous cords between the fragments of clavicle, or between the acromion (or sternum) and the clavicular fragment. Others have commented on the absence of such cords. Occasionally, small defects only are present, with a pseudarthrosis existing between the fragments. In the six cases here reported, small sternal fragments were present in two cases and small sternal and acromial fragments in two; the fifth patient had bilateral sternal fragments but only one (left) acromial fragment. The sixth patient had a small defect in the sternal end of the right clavicle and no defect in the left clavicle.

The scapulae are typically small and of primitive appearance, and lie higher and nearer the axillae than usual, often projecting behind like small wings. The supraspinous fossae are frequently absent, and the acromial processes are wide and long. If the acromial ends of the clavicles are present, the articular facets may be in the usual position or may be on the outer margins of the acromial processes.

Anomalies in the humerus, ulna, and radius are unusual, although the shafts may be somewhat shorter than average. Partial or complete absence of the radius has been reported. More frequent abnormalities are the persistence of epiphyseal lines at the lower extremities of the ulna and radius, and shortening of the radius out of proportion to the ulna, with consequent abduction of the wrist and hand.

Anomalies are common and numerous in the metacarpals and phalanges. In the child, extra epiphyses are encountered in the proximal ends of one or more metacarpals and in the distal ends of one or more phalanges, especially the proximal phalanges. The metacarpals are widened at the ends and narrowed in the shafts; the second metacarpal is usually disproportionately long. The cortex is dense in the constricted areas and is thin elsewhere.

The proximal phalanges are wide above, and narrow and dense distally. The middle phalanges are apt to be short, with slightly concave margins. The terminal phalanges are short and tapering, and lack the normally expanded ungual tuberosities. All phalanges of the little finger are unusually short.

Spine, Pelvis, and Thorax

The spinal abnormalities most frequently encountered are accentuations of the normal anteroposterior and lateral curvatures (lordosis, kyphosis, and scoliosis), fusion defects of the laminae and spinous processes (spina bifida), accessory vertebrae, missing vertebrae, and hemivertebrae. When a hemivertebra is present, as in one of the cases here reported, a marked localized scoliosis results. Cervical ribs are seen occasionally. The lower sacral segments and the coccyx are often absent or defective.

The pelvic bones are usually smaller than normal and have a somewhat primitive appearance, resembling in shape those found in the gorilla. Although small in size, they are thick and heavy, with flaring, asymmetrical iliac crests. The most common defects

are in the ossa pubes, which are underdeveloped and partially deficient mesially. As a result, the symphysis pubis is greatly widened, often measuring several centimeters in transverse diameter. The pelvic canal may be contracted and asymmetrical, which in the female predisposes to difficult or impossible delivery. In spite of these abnormalities, many women have been able to bear children without notably difficult labors, although a few have been delivered by Caesarean section. The wide sacro-iliac joints and symphysis pubis apparently account for the ease of delivery in some cases.

Fusion defects have been noted between the pubic and the ischiatic rami; the posterior inferior spines may be long and narrow, and the acetabula may be shallow.

The ribs are somewhat rounded behind and flattened in front. If spinal anomalies are present, compensatory changes of various types may be noted in the shape and position of the ribs. The sternum may be normal, or it may be small and irregular in outline.

Lower Extremities

The femoral necks are frequently deformed or absent; the infantile type of coxa vara is a common abnormality. While this is usually bilateral, in a few cases it has been present on only one side (often the right), with a consequent short leg and limp. A coxa valga is sometimes encountered. The remainder of the femora, the tibiae, and the fibulae are usually normal, although they may be somewhat shorter than average. Rarely, genu valgum and absence of one or both fibulae have been encountered.

The changes in the ankles and feet are similar to those in the wrists, hands, and fingers. The calcaneus may be shortened and the astragalus may be narrow. Supernumerary metatarsals and digits are occasionally seen.

Muscles

In most cases the muscular development about the neck and shoulders is normal; the muscles which normally are attached to the clavicles are attached to the rudimentary bony stumps or to the fibrous cords, which may be present in place of the deficient bones. Occasionally there is partial or complete absence of the subclavius, the clavicular head of the pectoralis major, the clavicular end of the trapezius, and the clavicular portion of the deltoid. The sternomastoid and sternohyoid muscles are usually present, and are attached to either the rudimentary sternal stumps of the clavicles or to the upper, outer margins of the sternum. The muscles normally attached to the supraspinous fossae of the scapulae are attached to the spines or to the acromial processes. Almost no other muscular abnormalities are found in this condition.

Nervous System

In the majority of cases, the mentality of the patients was reported as normal; neurological and mental lesions were occasionally encountered, however, and a few patients were psychotic or feeble-minded. Brain and cord lesions were reported by several authors, and included syringomyelia, cysts of the frontal lobe, and inflammatory and hemorrhagic lesions of the brain. An autopsy of Stewart's patient showed agenesis of the cingular gyri and of the left caudate and lenticular nuclei. Autopsy examination of one of the author's patients (Case 1) revealed no abnormalities in the brain.

Pressure by the clavicular fragments on the brachial plexus, with consequent neurological symptoms, was reported in at least two cases. In one instance, the symptoms were alleviated by removal of the defective bone.

Miscellaneous Findings

Hematological findings have been variable. Blood-calcium and blood-phosphatase determinations have been, as a rule, within normal limits; blood-phosphorus readings have been normal or slightly low. Blood dyscrasias have been reported, but the majority of the patients have had normal blood pictures. Basal metabolic readings have usually

been normal; a few have been high. Muscular deformities of the feet (talipes cavus and calcaneocavus) and inguinal herniae have been reported. Blue sclera was noted in one case.

General Appearance

The appearance of most of the patients is strikingly similar; in spite of racial differences, there is almost a family resemblance. The dysostotic individual is usually small of stature and slightly underweight, and when standing tends to accentuate the normal anteroposterior curves of the trunk; the head is held forward and the shoulders droop forward and inward. The somewhat overlarge and broad cranium, with prominent bosses and depressed median sulcus topping the small-featured, recessive face and prominent underslung jaw, is seen again and again in photographs of cases reported from all parts of the world. The eyes are widely spaced and sunken; the base of the short nose is broad and flat.

The neck is usually rather long and slopes toward the shoulders. The upper chest lacks the fullness normally present in the clavicular areas. The most characteristic feature of the shoulders is their unusual mobility. While this is largely due to the absence of the supporting and splinting effect of the clavicles, the scapular attachments appear to be much looser than those of normal individuals. In many instances, the shoulders can be bent forward so that they touch or nearly touch below the chin, and many of the case reports contain photographs of patients with the shoulders in this position.

Apparently the defects in the shoulder girdle are of little or no significance as far as function is concerned. No cases were found where patients had complained of difficulty in using their arms or shoulders, either in work or in sports. One of the author's patients was a baggagemaster, who was able to handle heavy trunks and crates without difficulty.

The hands have a rather striking appearance, because of the unusual length of the index fingers and the shortness of the little fingers. The terminal phalanges of all fingers are short and the nails curve in both anteroposterior and transverse diameters.

Clinical Features

Most of the patients are in fair health. Frequently they have consulted their physicians because of some unrelated complaint, and the bone anomalies were discovered in the course of physical examinations.

FIG. 1-A

Case 1. Note wide suture lines with wormian bones, underdeveloped facial bones, prognathous mandible, and unerupted teeth.

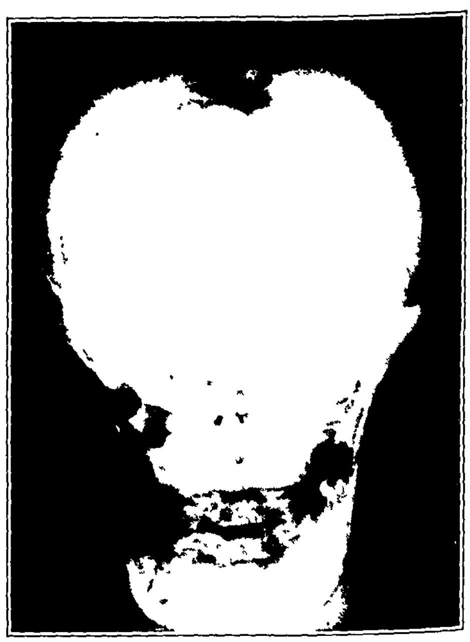

FIG. 1-B

Anteroposterior roentgenogram demonstrates brachycephalia, open fontanelles, and malposed unerupted teeth.

FIG. 1-C

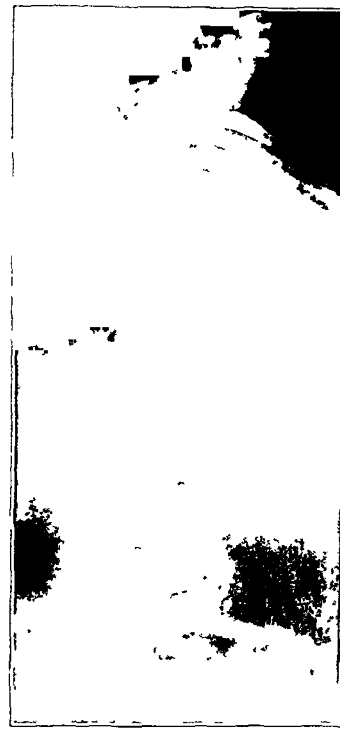

FIG. 1-D

Fig. 1-C: Small right sternal stub of clavicle appears over the first rib. Left sternal stub is concealed by the spine.

Fig. 1-D: Marked thoracic scoliosis is produced in part by a fifth thoracic hemivertebra.

Fig. 1-E: Heads, necks, and lesser trochanters of femora are underdeveloped, and the symphysis pubis is wide

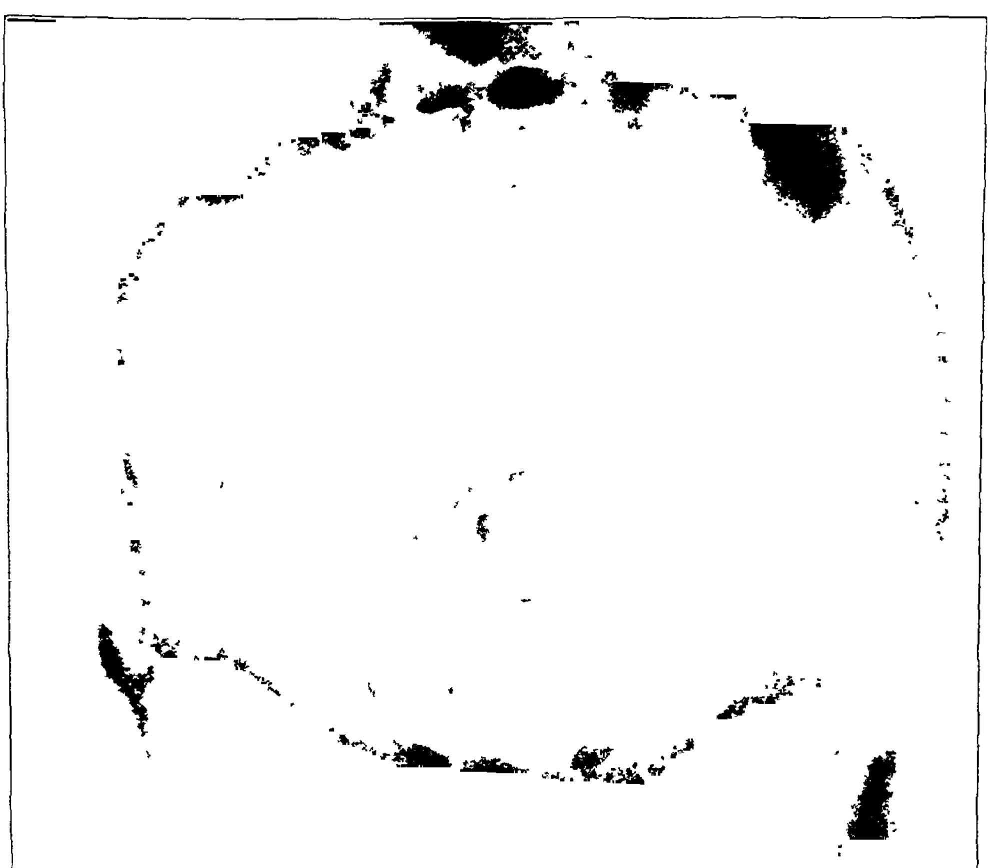

FIG. 1-E

As previously stated, the most troublesome defects are the dental abnormalities, with their attendant complications. If the arches of the feet are poorly developed, or if there are such conditions as genu valgum, coxa vara, or coxa valga (especially if it is asymmetrical), difficulties in gait and posture may be experienced. If the pelvis is contracted, normal labor may be impossible. If spinal anomalies are present, especially hemivertebrae, spina bifida, or extreme lordosis, kyphosis, or scoliosis, symptoms referable to these abnormalities may appear. Treatment is aimed toward alleviation of symptoms produced by the defects.

CASE REPORTS

CASE 1. A white male widower of old American stock, a retired baggagemaster, seventy-two years of age, was admitted to the medical ward of the Mary Fletcher Hospital, Burlington, Vermont, on April 10, 1937, in a semicomatose condition. The patient was confused as to time and events, and a satisfactory medical history could not be obtained. Apparently he had been troubled for several months by palpitation, dizziness, dyspnoea on slight exertion, and orthopnoea. At the time of admission to the Hospital, he was moderately dyspnoeic and cyanotic. The cardiac apex impulse was noted in the left fifth interspace, ten centimeters from the midsternal line, and was heaving in character. The apex rate was sixty-two per minute and the rhythm was irregular. The blood pressure was 140/100. An electrocardiogram showed evidence of left bundle-branch block. The tentative diagnosis was coronary sclerosis with probable occlusion.

In the course of the physical examination, it was noted that defects were present in both clavicles, and that the shoulders were unusually mobile. Narrow bits of bone or cartilage, about five centimeters in length, were palpable just above and external to the sternum; the remainder of each clavicle was missing. Palpation revealed the presence of a firm cord or band between the outer end of each bony fragment and the corresponding acromial process.

The cranium was broad, with a depressed furrow extending across the vertex from the glabella to the lambdoidal suture, and with prominent frontal, parietal, and occipital bosses. The face was small and sunken; the lower jaw was prognathous and contained several partially erupted teeth in the incisor region.

The chest was barrel-shaped and there was very little costal movement during respiration. The abdomen was flat and of normal appearance. There was a marked, high thoracic scoliosis and lumbar lordosis. The pelvis was tilted sharply forward. The thighs and legs were emaciated, and a slight genu valgum deformity was present. The fingers on both hands were somewhat misshapen and bent, as if old fractures had healed in abnormal positions.

Within a few days, the patient's clinical condition improved sufficiently to permit a roentgenographic examination of the skull, shoulders, chest, spine, and pelvis. The findings included almost all of the bone defects noted in other severe cases of mutational dysostosis. The skull showed marked brachycephalism, with a cephalic index of 84 degrees, a facial angle of 53 degrees, and a basal angle of 135 degrees. The suture lines were wide and tortuous, enclosing numerous large wormian bones in the lambdoidal and parietotemporal sutures. The coronal and metopic suture lines were open and wide. The facial bones were underdeveloped; defects were present between the malar bones and zygomatic arches. The mandible was prognathous and contained two partially erupted permanent teeth. In addition, there were a number of incompletely developed, unerupted teeth in both upper and lower jaws.

The fifth thoracic vertebra was a hemivertebra, which produced marked localized scoliosis. In addition, there was a long thoracic kyphosis and a lumbosacral lordosis. Fusion defects were present in the posterior arches of the upper three thoracic vertebrae and the fifth lumbar vertebra; the latter was partially sacralized. The pelvis was tilted sharply forward; the symphysis pubis was wide and the acetabula were shallow.

There was marked bilateral coxa vara; the femoral heads, necks, and lesser trochanters were underdeveloped. The greater trochanters were unusually large and high.

Bilateral clavicular defects were present. The sternal ends were short and narrow; the acromial ends were short, triangular bones which articulated with the outer margins of the acromial processes. The acromial processes of the scapulae were wide and prominent, and the coracoid processes were small. There was absence of the supraspinous fossae.

FIG. 2-A

Case 2. Many teeth are deciduous; the permanent incisors are malposed and poorly developed.

The bones of the arms, forearms, and wrists were normal. The second metacarpals were greatly elongated with constricted shafts; the other metacarpals were much shorter. The proximal phalanges were wide and slightly elongated; the middle phalanges were short, with narrow shafts and expanded ends; the distal phalanges were triangular, with underdeveloped terminal tufts.

Blood counts were normal except for the presence of slight anaemia and neutrophilic leukocytosis. The non-protein nitrogen was forty-eight milligrams per 100 cubic centimeters of blood.

The patient improved slightly for several weeks, and then developed signs of myocardial weakness and died on May 2, 1937.

The findings at necropsy were as follows:

One coronary artery was completely occluded by sclerosis, with infarction of the myocardium; the heart weighed 450 grams.

Examination of the skull revealed the findings described. The anterior fontanelle was stellate, depressed, and covered with a thin layer of bone derived from the inner table of the frontal bone; it measured five by ten centimeters in diameter. The mastoid fontanelles were incompletely closed. There was considerable thickening of the calvarium in the regions of the frontal, parietal, and occipital bosses.

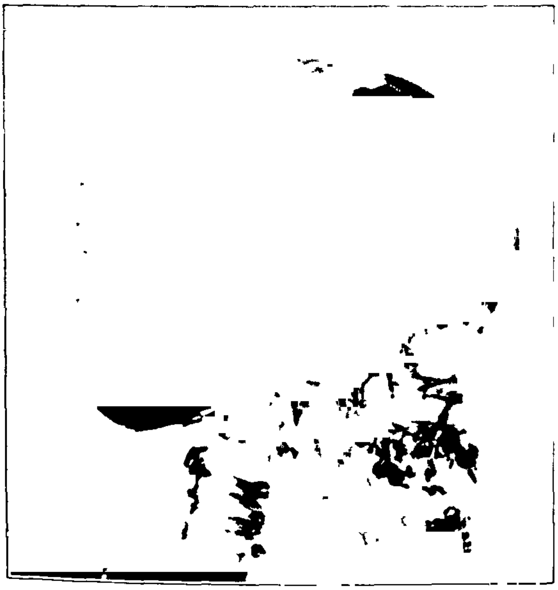

Fig. 2-B

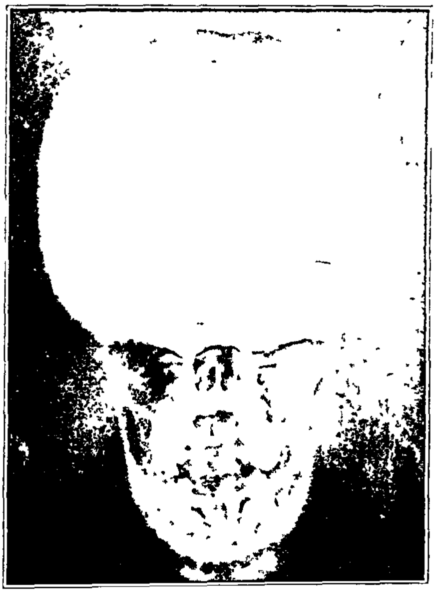

Fig. 2-C

Fig. 2-B: Lateral view of skull demonstrates wide suture lines with wormian bones, open anterior fontanelle, prognathous mandible, and multiple deciduous and unerupted permanent teeth.

Fig. 2-C: Showing the open fontanelle and metopic suture.

Fig. 2-D

Showing the sternal stubs of the clavicles and fusion defects in the upper thoracic spine.

FIG. 2-E
Upper teeth.

FIG. 2-F
Lower teeth.

The sphenoid and temporal bones were small and poorly developed; all of the normal foramina were irregular in outline, but they were not constricted. The mastoid processes were only partially pneumatized, and were composed largely of dense, compact bone. The squamous portions of the temporal bones were thick and dense, and faced downward and outward, forming part of the base of the cranium.

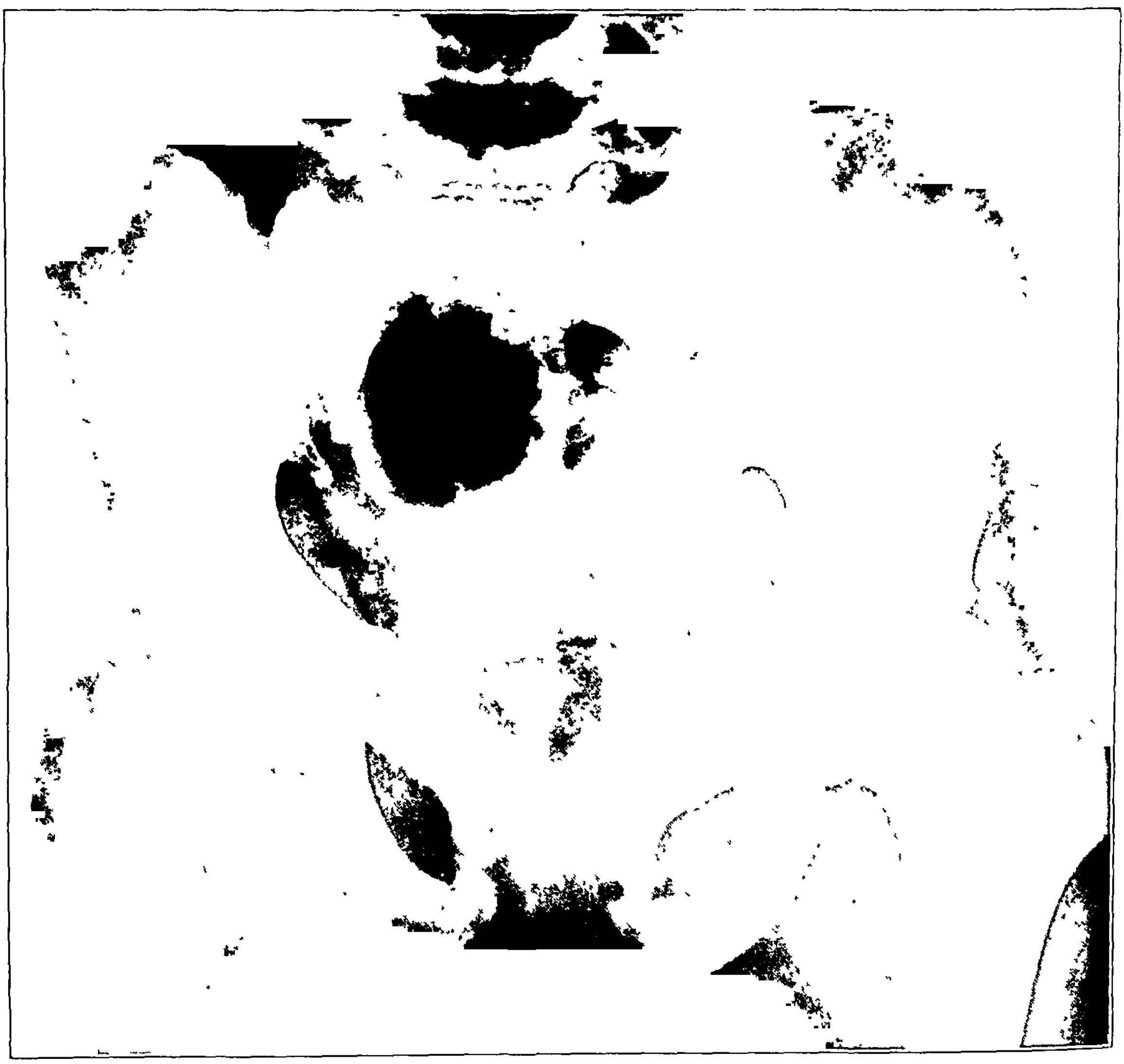

FIG. 2-G
The pelvis is anthropoid in type; the symphysis pubis is wide.

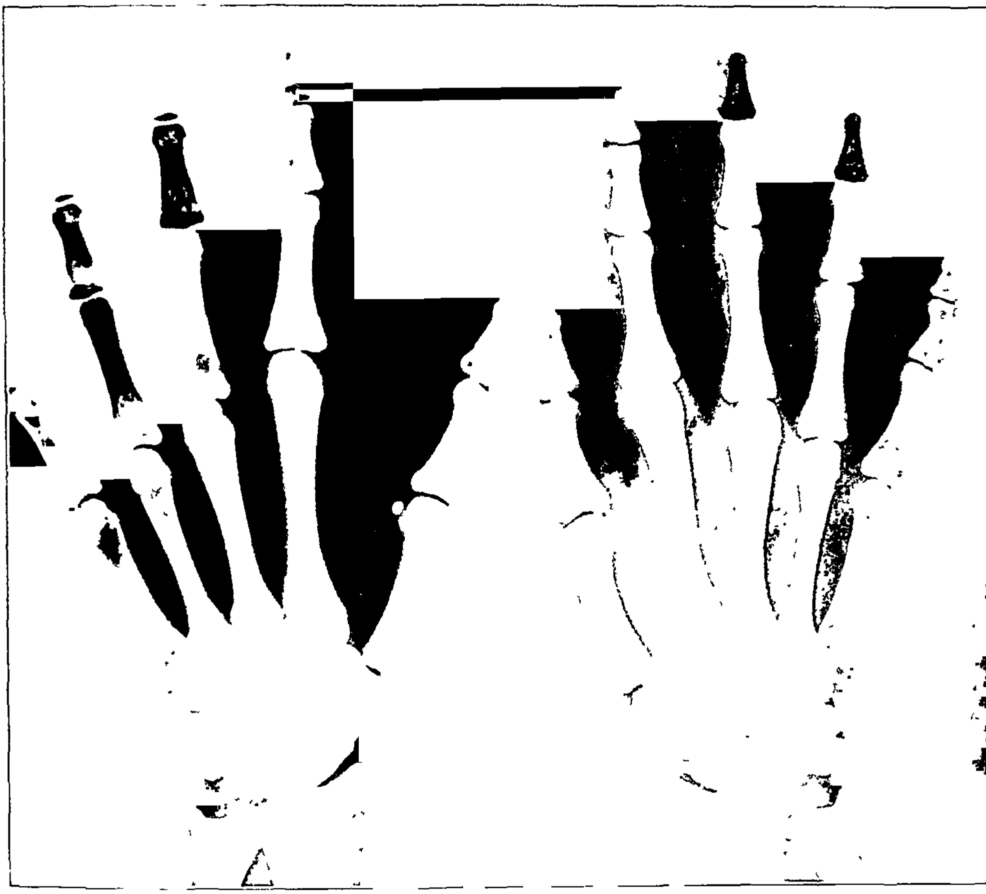

FIG. 2-H

The unusual length of the second metacarpal and the absence of tufts on the terminal phalanges are nearly constant findings in this disease.

The sternal ends of the clavicles were slender, and tapered to rounded lateral points. The right measured 5 centimeters in length and 1.2 centimeters in greatest width; the left measured 5.7 centimeters in length and 1 centimeter in width. The mesial ends articulated with the sternum; the tips were connected with the acromial processes by fibrous bands. The articular facets on the acromial processes were on their lateral margins. The acromial ends of the clavicles were triangular bones, 3.5 centimeters in length and 1.7 centimeters in width across the base.

The muscles which are normally attached to the inner half of the clavicle — the sternomastoid, sternohyoid, and subclavius — were attached to the sternal fragment of the clavicle. The subclavius muscle was greatly enlarged and showed additional attachments to the medial side of the base of the coracoid process of the scapula and to the fibrous band uniting the clavicular fragment with the acromial process.

The ossa pubes were only partially developed, and dense fibrocartilage was present in the region of the greatly widened symphysis pubis. The femoral necks were almost completely absent, the heads being attached directly to the upper shafts.

No developmental abnormalities were noted in the brain or the viscera. In addition to the cardiac disease, there was advanced arteriosclerosis with attendant changes throughout the body, and evidence of terminal congestive failure.

CASE 2 (only child of the patient described in Case 1), a woman, twenty-seven years of age, was examined in the Out-Patient Department. She stated that she knew very little about her father's family; she was aware of no definite case of the same disease in any other relative. She had noticed that she had unusually mobile shoulders, but she did not know that her clavicles were defective. She had always had difficulties with her teeth; the first dentition did not occur until she was two years old, and only a few permanent teeth had erupted at the time of examination. In other respects her health had been good. She had been married at the age of nineteen, and had given birth to a child two years later. Pregnancy and labor had been normal; the latter was of short duration and did not require operative procedure.

Physical examination revealed the typical facies and characteristics of mutational dysostosis. The diagnosis was confirmed by roentgenographic examination. The cranium was brachycephalic with a cephalic index of 82 degrees, a facial angle of 58 degrees, and a basal angle of 146 degrees. The skull showed practically all of the abnormalities noted in her father's. There were numerous unerupted, partially erupted, and malposed teeth, many of which were carious. The eyes were widely spaced, and the nose was broad and slightly recessed. The mandible was slightly prognathous.

The neck sloped downward to the shoulders, which were narrow and sagging, and faced slightly forward and inward. The shoulders were unusually mobile, and could be brought forward so that they nearly touched in front. Short sternal ends of the clavicles could be easily felt and seen; the right was four centimeters in length and the left was six centimeters. No acromial ends could be palpated or visualized by roentgenogram. There was no palpable evidence of connecting cords or other structures between the rudimentary clavicles and scapulae. The scapulae and bones of the upper extremities showed abnormalities similar to those noted in her father. The patient also showed multiple defects in fusion of the vertebrae, but no hemivertebrae or other spinal deformities were visualized.

Fig. 2-I

Fig. 2-J

Fig. 2-I: The talus and calcaneus are small and poorly developed.
Fig. 2-J: Showing blunting of tips of terminal phalanges of toes.

The pelvis was small and anthropoid in type. Large defects were present in the inferior pubic rami, with consequent great widening of the symphysis pubis. The postero-inferior iliac spines were elongated, and the sacro-iliac joints were wide and irregular in outline. There was slight bilateral coxa valga; the tarsal bones were short and the phalanges of the toes showed changes similar to those noted in the fingers.

The patient's seven-year-old daughter was examined and showed no abnormalities in skeletal, soft tissue, or dental development.

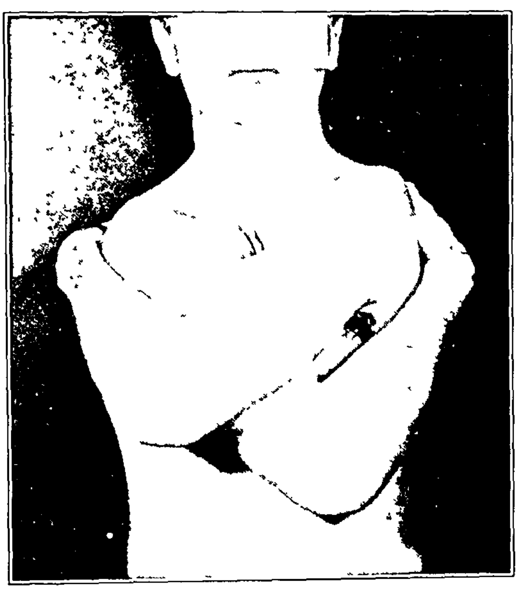

Fig. 3-A

Fig. 3-B

Fig. 3-A: Case 3. The defects in the clavicles allow unusual mobility of the shoulders.

Fig. 3-B: Most of the deciduous teeth have been extracted and only a few permanent teeth have erupted.

Case 3. A corporal, twenty-six years of age, received multiple shrapnel wounds of the neck, thorax, left hand, and ankle, while serving as a paratrooper in France. After several months of hospitalization overseas, he was returned to the United States with a partially healed compound fracture of the left calcaneus and with healed amputations of the left thumb and several fingers. Upon admission to the overseas general hospital it had been discovered that he had cleidocranial dysostosis.

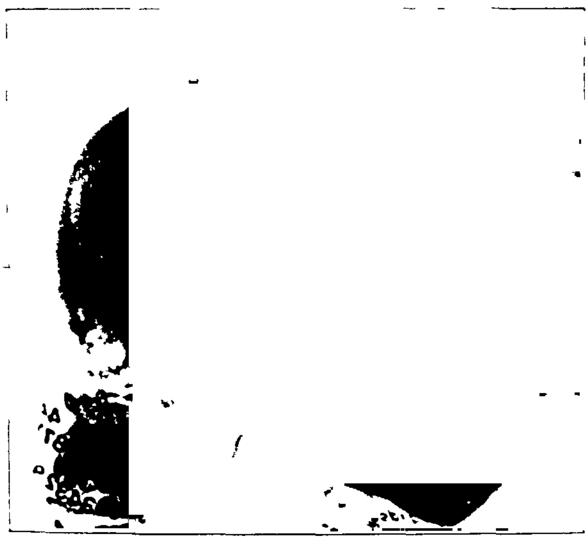

Fig. 3-C

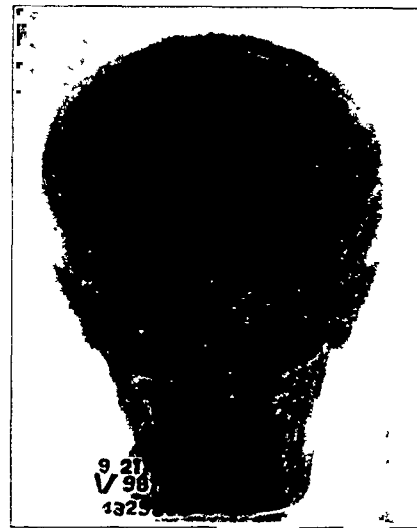

Fig. 3-D

Fig. 3-C: The cranial vault appears unusually large in comparison with the facial bones; wormian bones are present in the wide, tortuous sutures. An open mastoid fontanelle is visible.

Fig. 3-D: Brachycephalia and metopic suture are apparent.

The skull was brachycephalic, with a moderately kyphotic base and deep posterior cranial fossa. Small ovoid defects were present in the middle of an ununited metopic suture and in the regions of the mastoid fontanelles. Numerous wormian bones were present in the lambdoidal suture. The facial bones were underdeveloped and recessed. All of the deciduous, and many of the erupted permanent teeth, had been extracted. The remaining molar teeth were short and only partially erupted, and had a few enamel defects in the crowns Roentgenograms demonstrated numerous unerupted and partially developed teeth in both upper and lower jaws.

There was complete absence of the lateral halves of the clavicles; the outer ends of the medial fragments were slender with rounded tips. Fibrous cords, connecting the stumps of clavicles and acromial processes, could be palpated. The scapulae lacked supraspinous portions but had un-

Fig. 3-E

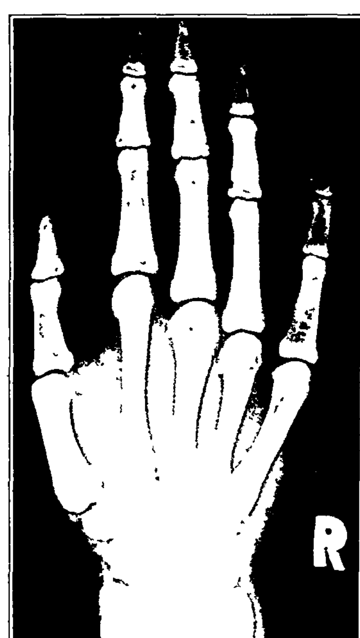

Fig. 3-F

Fig. 3-E: The sternal stubs of the clavicles, fusion defects in the upper thoracic vertebrae, and abnormalities in the scapulae are visualized.

Fig. 3-F: The bones of the hand and fingers have an appearance similar to that noted in Fig. 2-H.

usually large, wide, and long acromial processes. There was characteristic hypermobility of the shoulders (Fig. 3-A).

Fusion defects were present in the posterior arches of the lower two cervical vertebrae and of the upper three thoracic vertebrae. The fifth lumbar vertebra was partially sacralized, with large transverse

FIG. 3-G

Showing structural abnormalities in the ilia and ossa pubes.

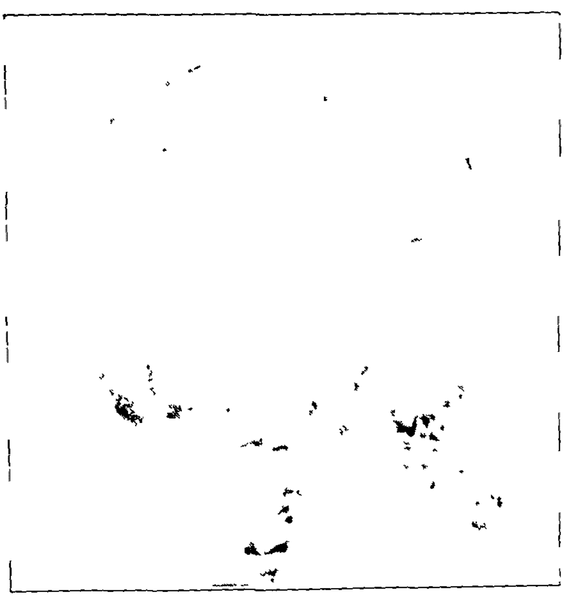

FIG. 4-A

Case 4. Lateral view of the skull demonstrates large anterior fontanelle and small mastoid fontanelle, wormian bones, prognathism, and supernumerary teeth.

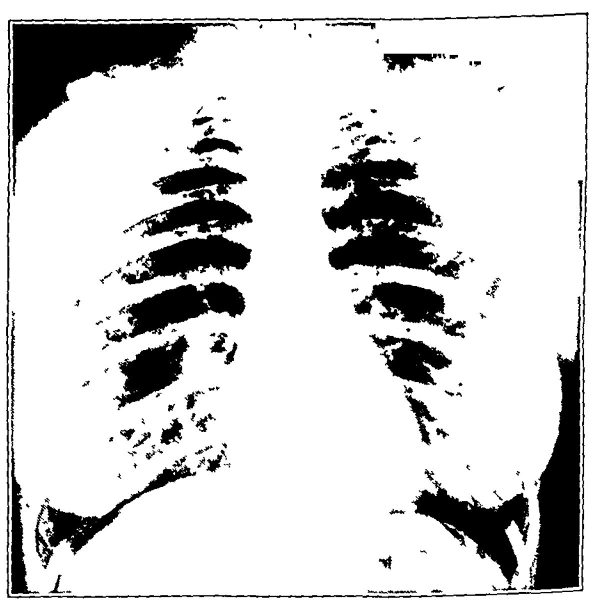

FIG. 4-B

The slender sternal ends of the clavicles are faintly visualized. Unusual mobility of the shoulders allows the scapulae to rotate anteriorly.

FIG. 5-A

Case 5. Large anterior, posterior, and mastoid fontanelles are visible.

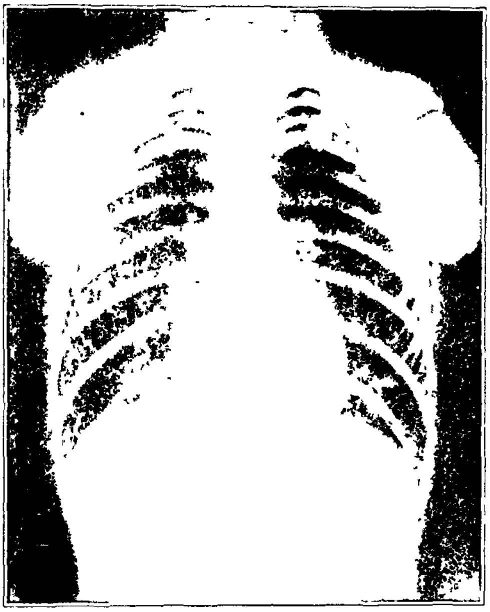

FIG. 5-B

Demonstrating the sternal ends of the clavicles and rotation of the scapulae.

processes articulating with the ilia and sacrum. The ilia were slender with high sloping crests. The bodies and rami of the ossa pubes were asymmetrical and irregular in outline, and there was slight widening of the symphysis pubis. Small accessory bones were present opposite the postero-inferior iliac spines.

There was moderate bilateral coxa valga. The femoral and tibial condyles were underdeveloped, the ends of the femora and tibiae being only slightly wider than the metaphyses.

There was characteristic lengthening of the second and third metacarpals and metatarsals, and of the proximal phalanges of the fingers and toes. The terminal phalanges were long and pyramidal in shape, with small terminal tufts. Although the epiphyses of the long and short bones were fused, narrow zones of bone sclerosis were present at the sites of the epiphyseal lines.

The patient was small in stature, but muscular and wiry. He was intelligent and alert, and had made an excellent combat soldier. He stated that his parents, grandparents, and several brothers and sisters were normal, and that he knew of no relatives who had abnormalities similar to his.

Two cases (Cases 4 and 5) appearing in a brother and sister were diagnosed in the course of a routine survey of school children, and were contributed through the courtesy of Dr. Louis Benson of the Vermont Tuberculosis Association. Inconclusive data are available regarding other members of the family. The father was said to have been normal in appearance; by a previous marriage he had had two normal children. The children's mother was not examined, but was reported by the public health nurse to have had facial characteristics and sloping shoulders similar to those noted in the children. One other child was said to be normal.

CASE 4. This fifteen-year-old girl had a brachycephalic skull. The metopic suture was ununited and the anterior fontanelle was open. Numerous wormian bones were present in the sagittal and lambdoidal sutures. There were many supernumerary unerupted permanent teeth, and most of the deciduous teeth still remained. The facial bones were underdeveloped, the base of the skull was kyphotic, and the mandible was prognathous.

There was a complete central defect in the left clavicle, with underdeveloped sternal and acromial stumps. On the right, a small sternal stump was present, but no acromial fragment had developed. Fusion defects were present in the posterior arches of the first and second thoracic vertebrae. The pelvis was anthropoid in type with slender, irregular ilia. There was absence of the descending rami of the ossa pubes and widening of the symphysis pubis.

CASE 5. This patient, a boy thirteen years of age, had somewhat similar findings. In addition to

FIG. 6-A

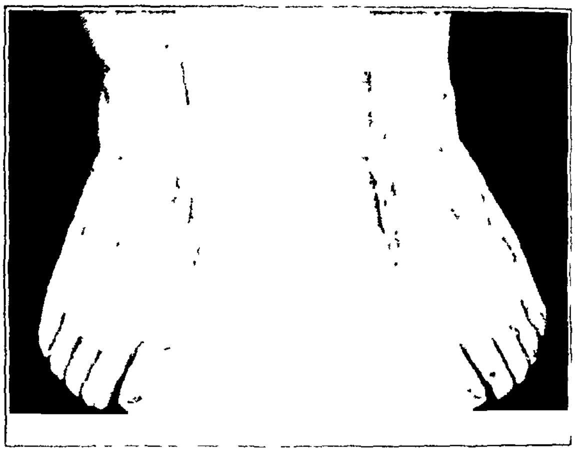

FIG. 6-B

Fig. 6-A: Case 6. The fingers are short and broad, and the nails show moderate onychogryposis.
Fig. 6-B: Changes somewhat similar to those noted in the fingers are present in the toes and toenails.

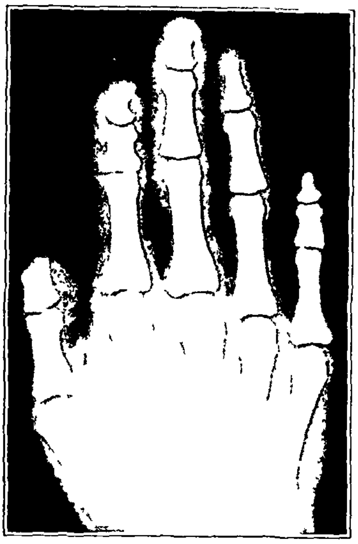

FIG. 6-C

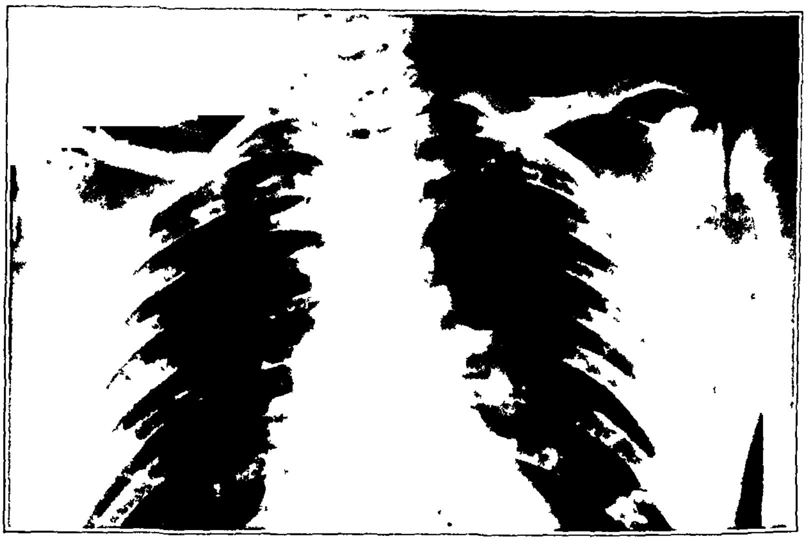

FIG. 6-D

Fig. 6-C: Characteristic changes are present in the metacarpals and phalanges.
Fig. 6-D: The right clavicle shows a small medial defect.

brachycephalia, open sagittal and metopic sutures and anterior fontanelle, the base of the skull was unusually kyphotic and the foramen magnum faced forward and only slightly downward. Central clavicular defects were present, and there was failure of fusion of the posterior arches of the seventh cervical vertebra and the upper six thoracic vertebrae. There was complete absence of both ossa pubes, but the remainder of the pelvis and the upper femora were of normal appearance.

CASE 6. A soldier, aged thirty-seven, was returned from overseas to Halloran General Hospital, because of impacted and unerupted teeth in the maxillae and mandible, with an infected dentigerous cyst in the mandible.

The patient was one of seven children; his parents, four sisters, and two brothers were free from evidences of dysostosis, as far as he knew. He had always enjoyed good health, with no complaints other than those relating to his teeth. The patient gave rather vague information about dentition, but stated that he had always had trouble with his teeth,—that they were poorly spaced in childhood and subject to caries, and that many of them were extracted early in life. He believed that only a few permanent teeth had ever erupted.

At the time of enlistment in the Army in 1937, the patient had eight erupted teeth,—six lowers and two uppers. These teeth were extracted in 1942, and he was fitted with dentures, which he has worn since. He had no further dental symptoms until June 1945, when severe pain in the right lower jaw developed. Roentgenographic examination in the dental department of an overseas Army Hospital revealed fourteen unerupted and poorly developed teeth in the maxillae and ten similar teeth in the mandible. Small cysts were noted about a number of these teeth. In view of the major dental problem involved, the patient was evacuated to the United States; examination revealed an infected dentigerous cyst, which was opened and drained.

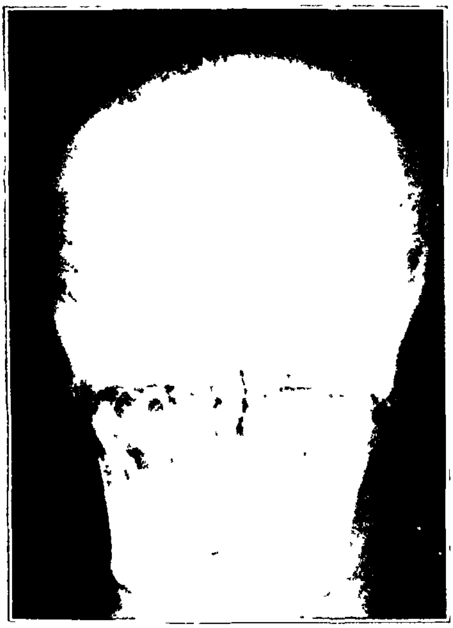

FIG. 6-E

Showing brachycephalia, a metopic fontanelle, depressed sagittal suture, and unerupted teeth.

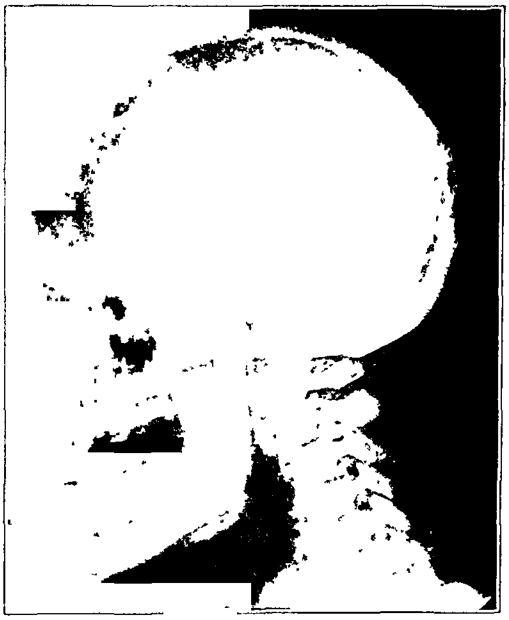

FIG. 6-F

Demonstrating wormian bones, prognathism, and poorly developed unerupted teeth.

Physical examination showed a man, short in stature (sixty-one inches tall), but fairly well developed, with evidence of good nourishment. The head was moderately brachycephalic; facial features were slightly recessive, and the mandible was slightly prognathous. There were no erupted teeth, and the patient was wearing dentures.

No significant abnormalities were noted in chest, shoulders, or abdomen. The fingers and toes were slightly short, especially the terminal phalanges, with a tendency toward clubbing. The nails showed a rather marked degree of onychogryposis,—more prominent in the toes than in the fingers. The nails were thickened, lacked luster, and were partly separated from the nail beds at the free edges.

Roentgenograms showed characteristic findings in all bones except the clavicles. There was moderate depression of the sagittal suture, and an ovoid defect was present in the lambdoidal suture. The bones of the face and of the base of the skull were underdeveloped; the mandible was large and prognathous. Most of the unerupted teeth resembled poorly formed cuspids, and had underdeveloped roots and irregular crowns.

The left clavicle was completely developed and showed no defect. The sternal end of the right clavicle was deficient, the bone ending medially in a rounded point. The scapulae showed slightly prominent supraspinous portions. Each os innominatum was slender and poorly developed; there was bilateral coxa valga.

The second metacarpals and metatarsals were unusually long, and the terminal phalanges of fingers and toes showed underdeveloped terminal tufts. There was an anomalous ununited epiphysis at the base of the second metatarsal.

COMMENT

In reviewing the descriptions of the developmental defects reported in the mass of material covered, one is impressed by the multiplicity and variability of lesions found in this disease. While certain bones, especially the clavicles and skull bones, have been involved in nearly all cases, there have been patients with mutational dysostosis in which these bones have been normal. Rhinehart's patient had normal clavicles, but characteristic lesions were present in the skull. Fitchet reported defective clavicles in six members of one family (three generations) all but one of whom had normal skulls,—the one exception, the youngest child, had delayed closure of the anterior fontanelle, wide suture lines, and a slightly prognathous jaw. In the author's Case 6, the patient had a small defect in one

clavicle only—and that at the extremity of the bone rather than in the mid-shaft—while characteristic lesions were noted elsewhere in the skeleton.

Therefore, the author agrees with Rhinehart that the term "cleidocranial dysostosis" should be replaced by the more accurate and descriptive term, "mutational dysostosis", and believes that the condition should be considered as one in which any or all of the many different defects may occur. As the condition is traced through additional generations of families, a better understanding should be reached concerning the factors of heredity which operate in its transmission.

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ARTHRODESIS OF THE HIP PRODUCED BY INTERNAL FIXATION

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During the past twenty-five years, orthopaedic surgeons have expended much effort on the problem presented by the elderly patient with painful, disabling arthritis of the hip. New surgical operations, such as acetabuloplasty, have been devised; and older operations, such as arthroplasty, have been modified. Although a great deal of good work has been done, there is still no completely satisfactory answer to the problem. The conventional method of arthrodesis, necessitating prolonged spica immobilization and inevitably resulting in a stiff knee, is not well tolerated by older patients. Furthermore, many patients who are not adverse to having an operation will instantly reject the idea of being bedridden in a cast for three or four months. A method was therefore sought for stabilizing the hip, which, without plaster immobilization, would permit early ambulation.

In 1935 Burns reported one case in which he had used a tri-flanged nail to fix the hip, and four years later he reported twelve more cases which were similarly treated. Six of these patients obtained a painless hip; one died of pulmonary embolism; one had no relief from pain; two suffered subtrochanteric fractures; and two patients had recurrent pain when the nail slipped. Watson-Jones reported "favorable results" in thirteen patients with malum coxae senilis treated by arthrodesis. Both of these authors used a tri-flanged nail, driven through the head of the femur and into the ilium over a guide wire from the subtrochanteric region. The position of the nail was checked by anteroposterior and lateral roentgenograms. Extrusion of the nail was prevented by a pin which fixed it to the lateral femoral cortex. No cast was applied, and the patients were ambulatory in ten days. No evidence was presented as to whether or not bony ankylosis developed. White operated upon seven hips which he fixed by nailing; two of the patients had an active tuberculous coxitis. Results were reported as encouraging.

Stimulated by the reports of Burns and of Watson-Jones, the authors performed the operation on several fresh cadavera. Fairly firm, immediate fixation could be obtained with the nail alone, but *both the rigidity and the strength of the fixation were greatly increased by inserting a screw through the acetabulum into the head, at right angles to the nail.*

The operative procedure described here has now been used a number of times, and the present state of the first twenty-four patients treated in this manner is recorded.

In this series, there were ten women and fourteen men. The youngest was twenty-one and the oldest seventy-one years of age; the majority were over fifty years old. Pain in the hip, thigh, or knee was the main complaint in all cases, and it was for this, rather than for any deformity, that the patients sought treatment. One patient was bedridden because of severe pain; others could get about only with the aid of crutches. None could work. Active flexion in the affected hips ranged from 40 degrees to 1 or 2 degrees in patients with a firm, fibrous ankylosis. Abduction, adduction, and rotation were usually impossible. The deformity of the affected extremity was usually one of adduction and external rotation. Severe adduction in some cases resulted in marked apparent shortening. The Trendelenburg test was positive in all cases. In only one patient was hypertrophic arthritis marked in both hips; in this patient, treatment of the less involved hip has not been necessary. Aside from their age, all patients were good operative risks.

Roentgenograms in all cases showed narrowing of the joint space, degenerative cystic changes in the sclerotic bone, and hypertrophic changes about the acetabulum. Shortening of the femoral necks and partial subluxation of the more severely deformed, flattened femoral heads existed to varying degrees.

Two of the patients had painful hips, one following a Smith-Petersen acetabuloplasty

and the other following a vitallium-cup arthroplasty. Three patients had traumatic arthritis. The remaining nineteen patients were diagnosed as having hypertrophic arthritis of the hip.

OPERATIVE TECHNIQUE

The patient is placed in the supine position, with the hip well toward the edge of the table. To ensure that the hip will be arthrodesed in the desired degree of flexion, sandbags are placed beneath the knee, and fixed to the operating table with adhesive tape before the extremity is prepared and draped. The draping is applied so that the limb is free, and so may be manipulated by the operator.

An incision is curved over the anterior half of the iliac crest, and carried longitudinally five inches down the anterior surface of the thigh, exposing the iliac crest and sartorius. The latter muscle is detached at its origin and reflected medially. With a periosteal elevator, the tensor fasciae latae and the anterior origins of the gluteus minimus and the gluteus medius are elevated and reflected laterally. The tendinous portion of the rectus femoris is divided close to the anterior inferior iliac spine, and the muscle is allowed to retract. The anterior surface of the capsule of the hip joint is exposed and incised transversely. The iliac part of the incision is then packed with sponges to control oozing.

The attachments of the abdominal muscles to the iliac crest are elevated, and subperiosteal dissection is carried beneath the iliacus muscle to below the arcuate line. Exposure of the iliac fossa is facilitated, if an operating table is used which can be tilted transversely, thus causing the abdominal wall and its contents to fall away from the operated side of the pelvis. This exposes the internal side of the innominate bone from the iliopectineal eminence almost to the sacro-iliac joint.

The hip is dislocated. The remaining cartilage and fibrous tissue are chiseled from the head of the femur and the acetabulum, and the denuded head of the femur is then replaced into the acetabulum.

Another incision is made through the skin, the fascia lata, and the vastus lateralis, exposing three inches of the femur in the subtrochanteric region. With a sharp gouge, the cortex is opened about one inch below the greater trochanter to receive the Smith-Petersen nail. Care must be taken not to destroy too much of the cortex, or the stability of the nail will be reduced. With the hip flexed 35 to 50 degrees and in the mid-position (adduction-abduction), the nail is driven through the femur and into the thick part of the innominate bone. An assistant places his hand in the iliac fossa so that it can be determined when the nail protrudes through the inner cortex of the pelvis. The exact angle at which the nail is inserted depends on the deformity and degree of subluxation of the head of the femur. In order to traverse the thick section of the ilium, it must, in most cases, transect the anterior superior portion of the femoral head. The femur is then impacted firmly into the acetabulum.

A hole is drilled through the pelvis and into the femoral head from the inner surface of the ilium in the region of the anterior inferior iliac spine. A Venable screw, three and one-half inches long, is inserted to prevent rotation of the head.

At this point the joint should be completely stable. If motion can be demonstrated on even vigorous manipulation, the operation will be a failure.

The fascia over the iliac crest is brought together with several interrupted sutures, reinserting the lateral and abdominal muscles, and the skin is closed. No cast is applied. A transfusion of 500 cubic centimeters of blood is administered during the operation.

COMMENTS ON OPERATIVE TECHNIQUE

It is imperative to use a sharp-pointed nail. A blunt nail penetrates the sclerotic ilium with difficulty, and may eject the femoral head, along with the nail, out of the

acetabulum. As an added precaution, the head is vigorously impacted into the depth of the acetabulum to assure continuity of the raw surfaces of the femur and the acetabulum. This is essential for the development of bony union.

It is most important that the nail, to secure fixation at its distal end, be driven through the thick part of the ilium which forms the anterior superior surface of the acetabulum. The ilium in this area is about one inch thick, in contrast to the few millimeters of bone composing the medial, central wall of the acetabulum (Fig. 1). The nail must be inserted into the femur at an angle of about 45 degrees, and directed slightly anterior. The exact angle depends on the amount of deformity and subluxation of the femoral head. If the nail is directed through the posterior inferior quadrant of the femoral head, it will pass through the thin portion of the acetabulum and well below the arcuate line, and may pass undetected into the pelvic cavity. Likewise, if the nail is inserted into the femur at an angle of much less than 45 degrees, it may strike the ilium too acutely and sheer off rather than penetrate the bone.

FIG 1

Frontal section of hip, demonstrating the course of the Smith-Petersen nail through the femur and into the thick portion of the pelvis, overlying the acetabulum

In the authors' experience, 35 degrees to 50 degrees of flexion is desirable. Less flexion than this makes it difficult for the patient to sit Although it has been suggested that the lumbar lordosis will permit adequate flexion if arthrodesis is performed with the patient's leg extended on the operating table, a few patients treated in this manner by the authors complained of inability to sit comfortably. No patient had complaints resulting from too much flexion. To facilitate placing the hip in adequate flexion, and in the neutral position with respect to abduction and adduction, heavy sandbags were placed beneath the knee before the limb was draped. Sandbags could not be employed when the hip was fixed by a firm fibrous ankylosis in partial flexion or marked adduction. Difficulty was encountered, especially with obese individuals, in estimating the degree of abduction or adduction. No hip was arthrodesed in abduction. A few were placed in adduction, but the shortening which resulted was easily taken care of by a lift on the patient's shoe.

In the first patients operated upon, a small-gauge screw was used, which fractured in one case (Fig. 8) and bent in another (Fig. 9) At present a large vitallium Venable screw, three and one-half inches in length, is utilized, which adds greatly to the stability produced by the operation. Ideally, the screw penetrates one and one-half inches into iliac bone, and *extends through the center of the head of the femur* (Figs 2, 3-A, and 3-B).

One fundamental variation in operative technique was tried on two patients who had a very firm fibrous ankylosis with a minimal degree of deformity. The hips were fixed with a nail and screw, without being dislocated. Several different surgical approaches were tried, but the one described proved most satisfactory. In a few instances extra-articular bone grafts secured from the iliac crest were used to ensure the ankylosis.

POSTOPERATIVE CARE

Most patients withstood the operative procedure well, and they were encouraged to move about in bed as soon as possible. They were usually up in a chair on the seventh day after operation. By the tenth day they were encouraged to use crutches, and were dismissed on crutches usually between the tenth and fourteenth days. If the hip was solidly fixed, they could bear full weight on the operated leg without pain. None of the patients who had painful hips when dismissed from the hospital secured a solid ankylosis. It is certain that a solid operative fixation was not achieved in these failures.

An effort was made to have all patients use crutches for two or three months after the operation; however, some patients discarded them earlier.

DISCUSSION

Fifteen of twenty-four patients operated upon obtained painless, stable hips (Table I).

TABLE I

RESULTS OF OPERATION

	Number of Patients
Painless stable hip	15
Pain and motion in hip	7
Wound infection	1
Postoperative deaths	1

Seven had motion and pain in their hips after operation. There was one postoperative death, which was caused by a pulmonary embolism. One wound infection necessitated removal of the nail and screw. The wound healed and a bony ankylosis resulted.

Three of the seven failures (Table II) were probably the result of fracture of the nail (Fig. 8). Two of these patients experienced a sudden sharp pain in the hip after a fall; however, the other patient could remember no instance of excessive strain upon his hip.

FIG. 2

Section through ilium and head of femur, demonstrating position of Venable screw.

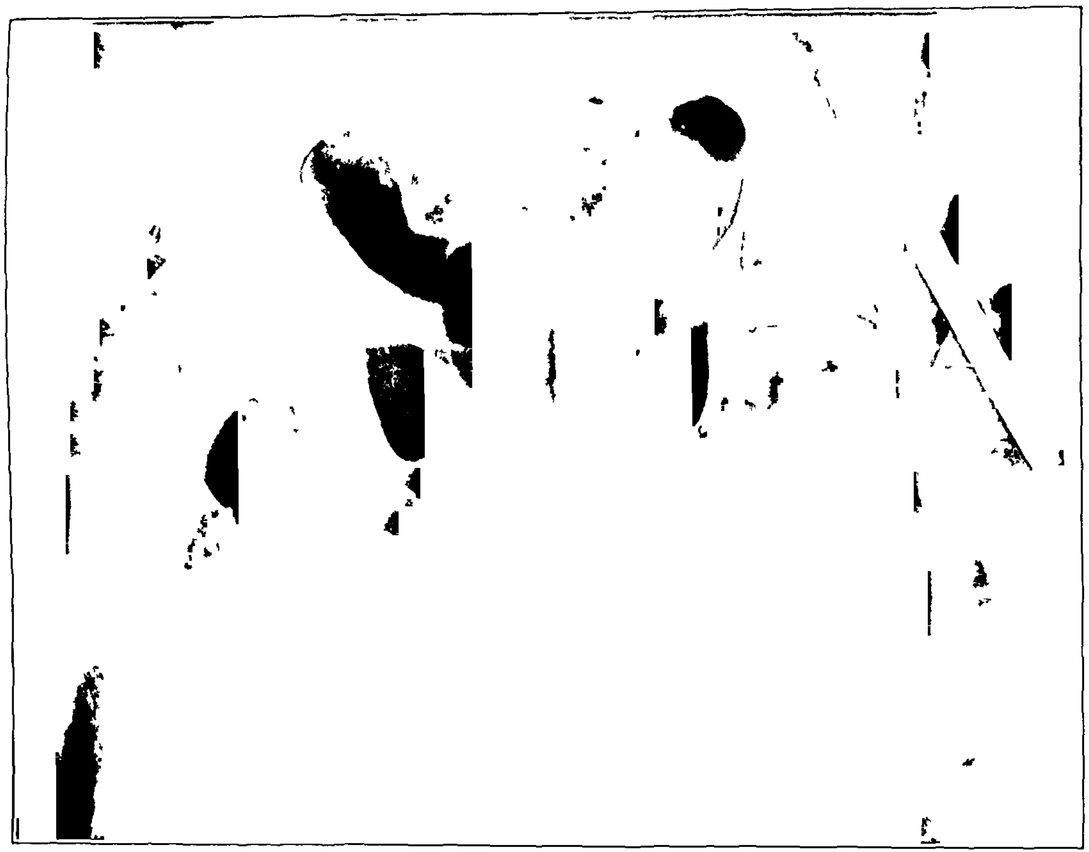

Fig 3-A

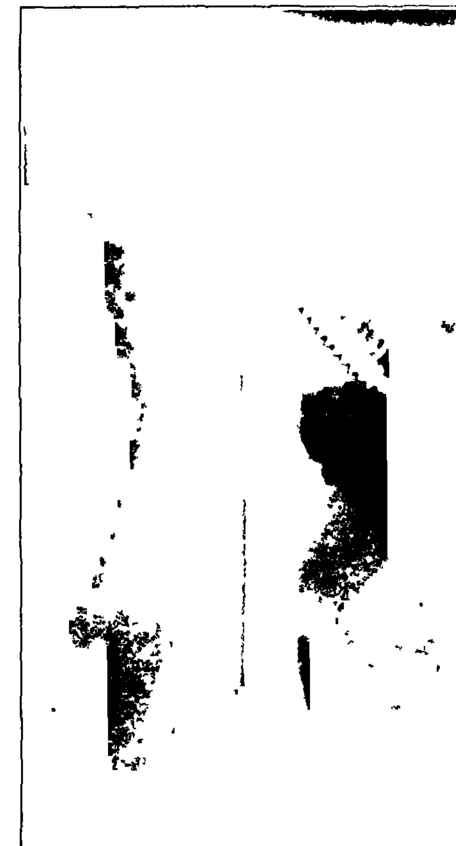

Fig 3-B

Fig 3-A Postoperative roentgenogram, demonstrating the Smith-Petersen nail well fixed in iliac bone The Venable screw, extending through the femoral head, eliminates rotation in the anteroposterior plane and prevents the femur from pulling away from the acetabulum

Fig 3-B Lateral roentgenogram, showing that the screw does traverse the femoral head.

FIG. 4-A

FIG. 4-B

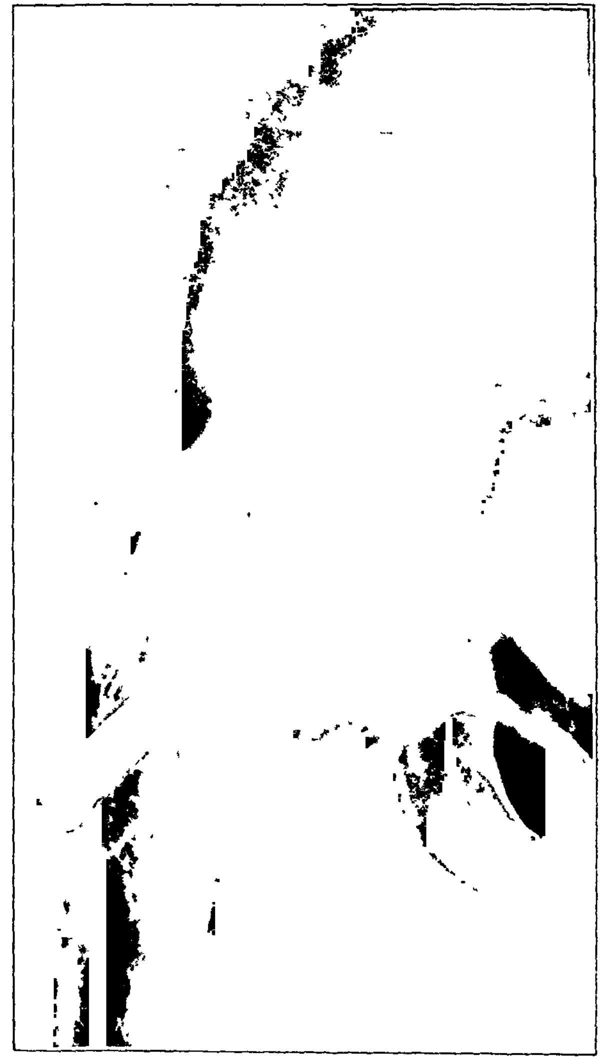

FIG. 4-C

Fig. 4-A: S. W. Preoperative roentgenogram, showing changes typical of hypertrophic arthritis.
Fig. 4-B: Postoperative roentgenogram. The hip is solidly fixed by a nail and two small vitallium screws.
Fig. 4-C: Roentgenogram taken three years and eleven months after operation. Bony trabeculae extend across the joint. The patient works as a laborer, and has no symptoms.

Fig. 5-A

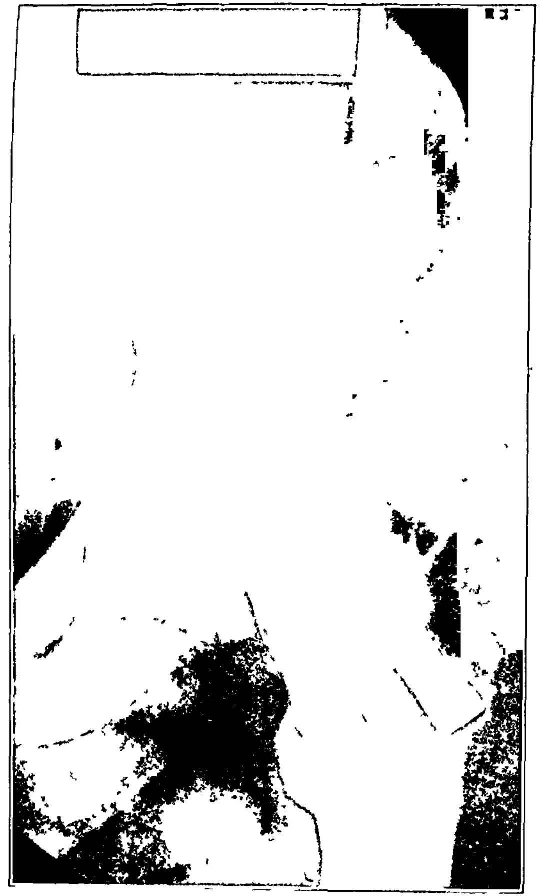

Fig. 5-B

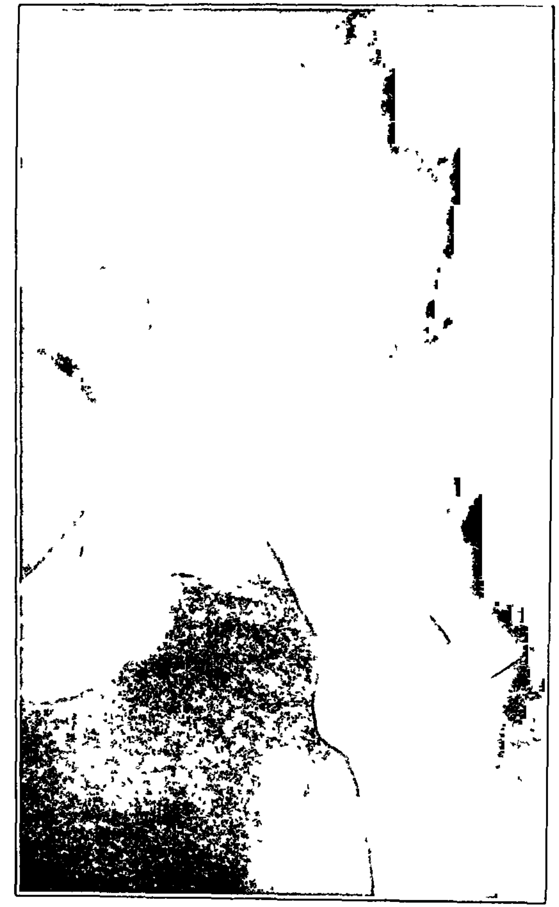

Fig. 5-C

Fig. 5-A: F. J. L. Postoperative roentgenogram of hip well stabilized by vitallium nail and screw.
Fig. 5-B: Six months after operation the joint space is still visible. Clinically the hip was solidly arthrodesed.
Fig. 5-C: One year and eight months after operation. Bony trabeculae extend across and obliterate the joint space, demonstrating that bony ankylosis can occur while the patient is ambulatory.

FIG. 6

M. S. Three years and five months after operation. A bridge of bone extends from the acetabulum to the femoral neck and head. The patient walks with no limp.

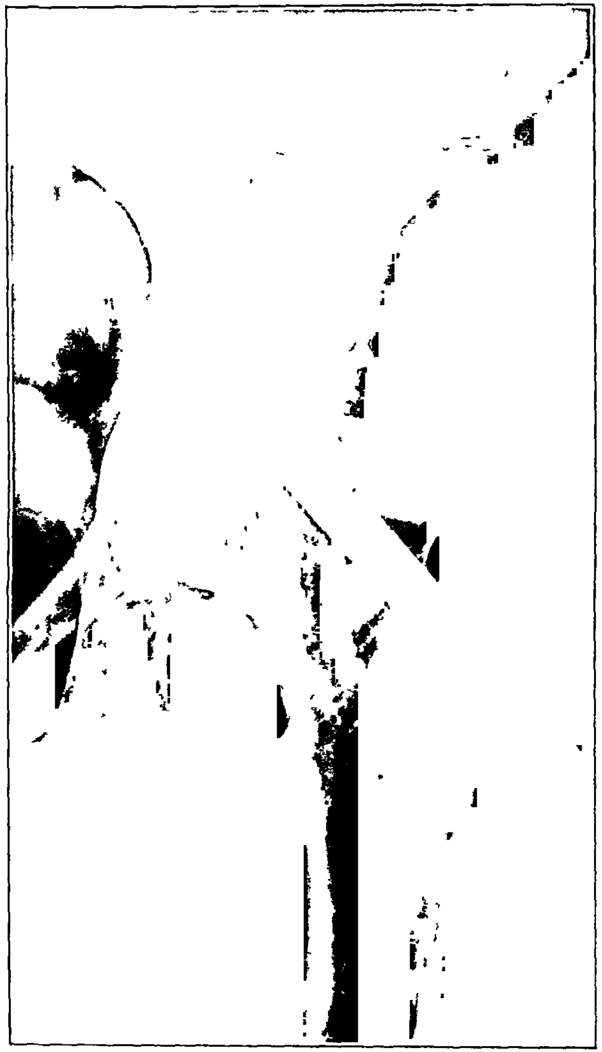

FIG. 7

A. D. Four months after operation. The hip is well fixed by a vitallium nail and screw. Clinically the hip is firmly arthrodesed.

FIG. 8

C. J. This patient fell down a flight of stairs eight weeks after operation, and experienced severe pain in his hip. The nail and screw evidently broke at that time, because he walked without pain before the fall.

Fig. 9

W. R. Postoperative roentgenogram. The nail was inserted into the ilium too acutely. Adduction of the limb in bed caused the nail to shear out and one screw to bend.

Fig. 10

J. L. Two and one-half years after operation. There is absorption of bone about the nail, allowing 40 degrees of hip flexion and extension.

Fig. 11

Nineteen months after operation, showing absorption around point of nail and aseptic necrosis of femoral head.

Pain and motion increased gradually. Another operation failed because the nail penetrated the pelvis too acutely, and sheered out when the patient moved in bed (Fig. 9). Resorption around the nail allowed motion in the hip in another case (Fig. 10). Aseptic necrosis of the remaining femoral head prevented ankylosis in one patient, who had previously been treated by a vitallium-cup arthroplasty. In another patient, in whom bony ankylosis did not occur because of inadequate fixation at the time of operation, necrosis of the femoral head eventually developed (Fig. 11). The longest follow-up period was four and one-half years; the shortest was six months.

TABLE II

CAUSE OF FAILURE

	Number of Patients
Broken nail	3
Nail incorrectly inserted	1
Resorption around nail	1
Aseptic necrosis of head of femur	1
Motion in hip after operation	1

Since three of seven failures can be attributed to fracture of the vitallium nail, this factor could perhaps be remedied by the use of a stainless-steel nail, which is less brittle. Because of similar experiences, Watson-Jones employs an oversize nail.

Of the fifteen patients who obtained good results, eight were men and seven were women. Two of the women use crutches when outside of the house, because of arthritic changes which developed in the other hip. One uses a cane for walking long distances. The eight men are working full time as laborers and have no pain in the hip.

Not all of the patients with satisfactory results have a bony ankylosis demonstrable by roentgenogram. The joint space may be discernible in roentgenograms for some time after the operation. Figures 5-A, 5-B, and 5-C demonstrate that six months after operation the joint space is still visible, but by twenty months bony trabeculae extend across the joint space.

Gross circulatory disturbances in the head of the femur may preclude a bony ankylosis, even though the hip is solidly fixed and raw bony surfaces are in contact. In these cases extra-articular grafts, turned down from the ilium to the femoral neck, increase the chance of a bony fusion.

CONCLUSIONS

The procedure described should be limited to older patients who have degenerative or traumatic arthritis of the hip. Marked aseptic necrosis, and a wide disparity of configuration between the head of the femur and the acetabulum, are definite contra-indications.

A vitallium screw placed through the acetabulum and into the head of the femur adds greatly to the stability secured by the Smith-Petersen nail. If there is motion in the hip at the end of the operation, this will increase as the patient moves about. To ensure complete stability, the nail must penetrate the thick part of the acetabulum.

This procedure provides immediate hip fixation and allows the patient to be up two weeks after operation.

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VERTICAL TRACTION IN THE EARLY MANAGEMENT OF CERTAIN COMPOUND FRACTURES OF THE FEMUR

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The treatment of compound comminuted fractures of the femur often requires more care for the soft tissues of the thigh than for the femur itself. The usual position of the extremity on the operating table, or on a special orthopaedic table, does not give circumferential access to the thigh for surgical procedures. The conventional methods of traction do not permit ready access to the posterior wounds which are so frequently present in the thigh. As an aid to operative management and as a temporary method of traction for the first few weeks after the operation, the vertical "90-90-90 traction" was devised and was found to be satisfactory.[1] Essentially, this method consists of exerting traction on the femur while the hip, knee, and ankle are each flexed at 90 degrees.

In the operating room an overhead frame may be improvised by clamping a cross bar to two wooden transfusion stands, one at each end of the table. A pulley is attached to the cross bar directly over the hip of the involved extremity. A Kirschner wire is inserted just above the condyles of the femur, or, if wounds involve the lower thigh, it is inserted in the tibial tubercle, and traction is directed over the pulley so that the femur is held at right angles to the table. Enough pull is exerted to lift the buttock slightly off the table, and the traction cord is fastened to the transfusion stand at the head of the table. The proper position of the knee and foot is best obtained by applying a piece of stockinette to the leg, splitting it under the heel to prevent its slipping off, and tying the loose end to the cross bar above the toes. If skeletal traction is not available or feasible, the position of vertical traction can be obtained by a suitable sling under the calf (Fig. 1).

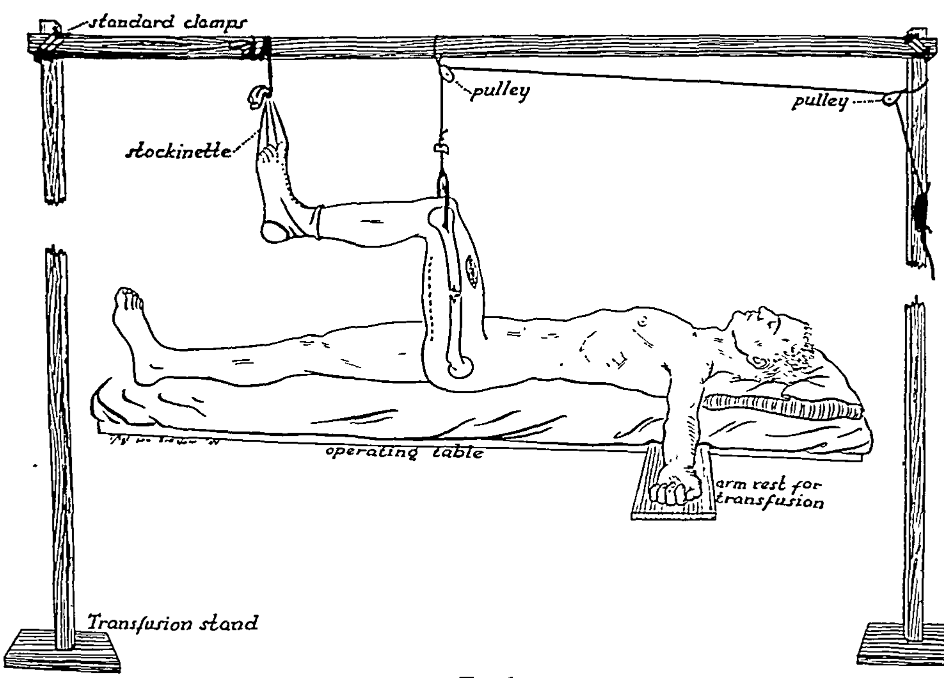

FIG. 1

Position of patient in 90–90–90 traction for surgery. The Kirschner wire may be placed in the upper tibia or lower end of the femur. If skeletal traction is not available, this position may be maintained by slings under the leg.

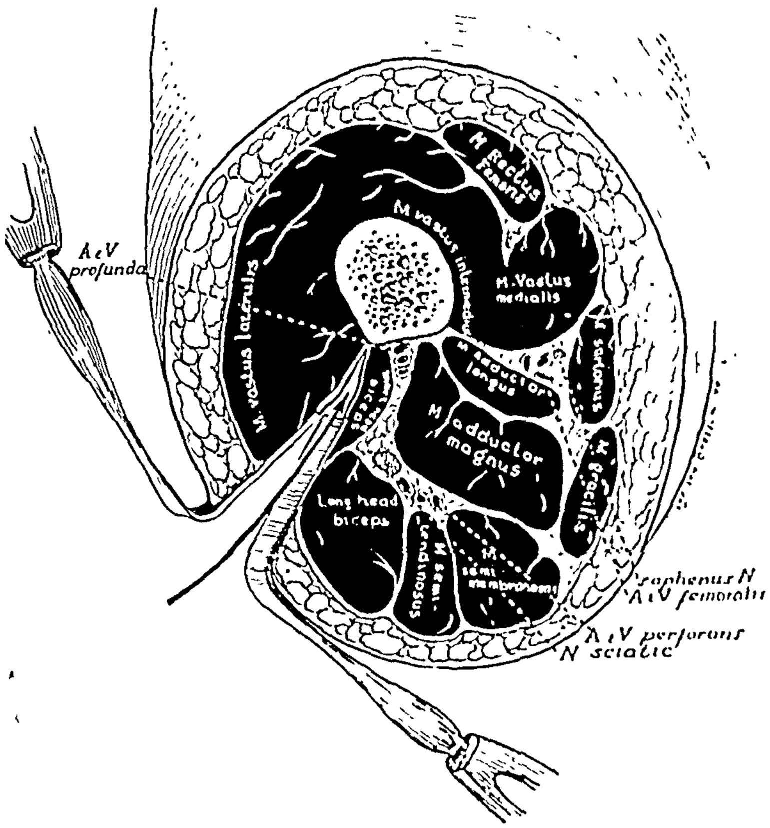

FIG. 2

Posterolateral approach to the femur between the vastus lateralis and biceps femoris. Mid-third of right thigh (after Gray).

Experience with over 250 battle fractures of the femur has proved the value of this method of traction in the operative management of the fracture. The great frequency of multiple and extensive wounds of the soft tissues, especially combined anterior and posterior wounds, makes it necessary to approach the thigh from every direction. Traction to the femur with the hip flexed at 90 degrees allows excellent circumferential access to the thigh, and permits wounds at any location to be approached with ease. By maintaining a steady and uninterrupted pull on the femur, this method prevents unguarded motion at the fracture site during the preparation and draping of the extremity, and at the same time corrects the overriding of the fracture ends.

In the initial débridement of the soft-tissue wounds, vertical traction permits the entire operation to be carried out with the patient on his back. To change the patient from the supine to the prone position during the operation, in order to explore and débride posterior thigh wounds, requires additional handling of the fractured extremity, as well as additional preparation and draping of the thigh. Not only is this time-consuming, but further injury to the soft tissues, vessels, and nerves by the fracture fragments may result.

In the reparative management of this fracture in a base hospital, the patient is brought to surgery in a spica cast or a Tobruk splint. After anaesthesia has been induced, the anterior half of the cast is removed, a Kirschner wire is placed in the distal femur or proximal tibia, and the extremity is suspended in 90-90-90 traction. The posterior half of the cast is then withdrawn, and the thigh can be shaved, washed, and draped without risk of displacement of the fracture.

Despite a careful débridement, there is often an accumulation of blood, tissue debris, and even pus in the wound. Provisions for dependent drainage of dead space must be made. In the author's experience, a posterolateral approach to the femur between the vastus lateralis and the biceps femoris is the best incision for this purpose (Fig. 2), and is facilitated by having the femur in vertical traction. It is also a valuable elective approach to the fracture site for open reduction and internal fixation of the occasional compound fracture which lends itself to this type of surgery. Excellent exposure is obtained by this route, and dependent drainage is assured, if the proximal portion of the incision is left open for spontaneous closure. Invariably the wound is completely healed by the time the fracture is united.

This method of traction is also employed for the external skeletal fixation of selected fractures, using the pins and couplings of the Roger Anderson apparatus. The fracture is reduced by 90-90-90 traction before the pins and couplings are applied. The reduction can often be confirmed by direct vision or palpation, but may be checked by a portable

roentgenographic unit. This method is considerably easier than using the special reduction machine and a fluoroscope. The author has found that the patient is more comfortable when external skeletal fixation is used after the fracture has been reduced. Pins which are inserted prior to the manipulation pull painfully on the soft tissues during and after the reduction, and the fixation apparatus is poorly tolerated.

As a method of traction on the ward, vertical traction in the 90-90-90 position has a limited use in femur fractures which are compounded by wounds of the posterior thigh. It is not intended to take the place of conventional methods of traction, utilizing the Thomas-Pearson splint. The femur is suspended to the Balkan frame by a weight, suitably directed over pulleys to maintain the thigh perpendicular to the. bed. Comfortable right-angle flexion of the knee is best obtained by a standard Pearson knee attachment,

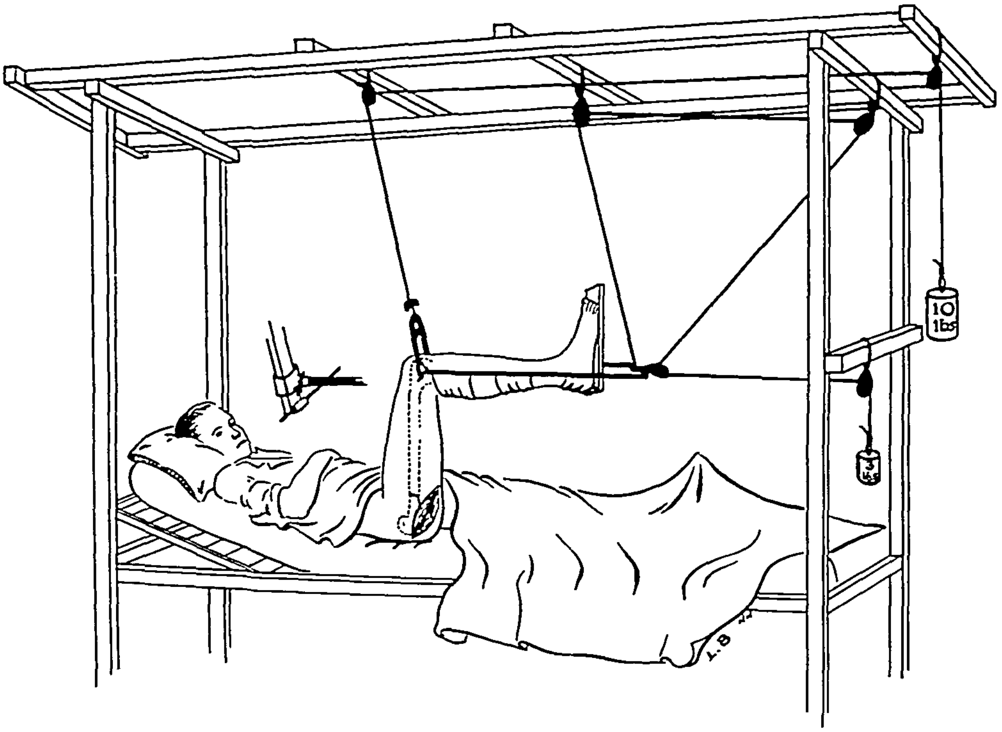

FIG. 3
Position of patient in 90–90–90 traction in bed.

fastened to the Kirschner wire bow. By a compound pull, a three-pound weight is sufficient to balance the leg in a position parallel to the bed. The foot is maintained at 90 degrees by a foot rest, which is added to the Pearson attachment (Fig. 3).

Soft-tissue care is most troublesome during the first few weeks of traction, and it is for this period that vertical traction offers advantages over the conventional methods. The method is simple and requires no special apparatus or skill. The patient is comfortable, and may use the bedpan without disturbing the alignment of the fracture. Dressings can easily be changed, as there is no interference by splint bars or slings. Wounds of the posterior thigh are as accessible as anterior wounds, and sutures and drains can be removed with ease. Snug compression dressings can be applied, and changed frequently, without displacing the fracture. The absence of a splint ring facilitates perineal care. Portable roentgenograms can be made in both planes without the annoying obstruction of opaque splint bars.

After a few weeks of vertical traction, the extremity should be brought down onto a conventional splint for the remaining period of traction. By this time the soft-tissue

wounds should be healed, if treated by secondary closure, or should have superficial granulations, if allowed to close spontaneously. Such disabilities as stretching of the quadriceps tendon or patellar ligament, contracture of the hamstrings, or fixation of the patella were encountered in several patients who were kept in the 90-90-90 position for periods of from eight to twelve weeks. No such disabilities were observed when this method was used for three or four weeks.

Restoration of length is easy by this method, and care must be exercised to prevent distraction, especially in patients with extensive loss of soft tissue or bone. In most instances, ten pounds of traction are sufficient; rarely will more than fifteen pounds be needed. Less weight is required to reduce fractures in the middle third of the femur than those at the trochanters.

Correct alignment by vertical traction can best be obtained in fractures involving the proximal third of the femur. Here the short proximal fragment is usually acutely flexed by the psoas pull, a position which relaxes the troublesome abductors and external rotators of the hip. The 90-90-90 traction has been employed with success in compound fractures of the neck of the femur. In fractures of the middle third of the shaft, it may be difficult to maintain alignment without coaptation splints, especially if there is considerable muscle destruction with consequent loss of the internal splinting effect of the intact muscle and fascial sleeve. Fractures of the distal third are better treated on the Thomas-Pearson splint, with or without combined traction of the tibia and femur.

Vertical traction, in the 90-90-90 position, for fractures of the femur should not be adopted to the exclusion of the conventional methods of traction; but when used in its proper place, it offers advantages in the management of difficult fracture problems, which are not afforded by other methods.

1. Obletz, B. E.: 90-90-90 Traction in Battle Fractures of the Femur. Med. Bull., North African Theater of Operations, Aug. 1944.

RESECTION OF THE CLAVICLE IN VASCULAR SURGERY

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In the approach to the great vessels at the base of the neck, the clavicle frequently prevents adequate exposure and control of the vessels proximal and distal to the vascular lesion. The safety of vascular surgery in this region depends largely upon the accuracy with which isolation of these structures is accomplished. It has long been recognized that the removal of a portion of the clavicle will greatly increase the exposure obtained, but the problem of subsequent clavicular repair has led to many variations in wound closure. Following subperiosteal removal of the segment, it is a common practice to replace the excised bone, using some type of wire or metal for fixation. Deformities, non-union, and pain frequently follow such a procedure.

Forty-eight patients in whom the clavicle has been partially removed have been operated upon at Ashford General Hospital for aneurysm and arteriovenous fistula of the subclavian, axillary, carotid, and innominate vessels and their branches. In lesions of the base of the neck and the superior mediastinum, resection of the medial half of the clavicle, together with its sternal articulation, has been performed in order to increase the exposure. The subclavian and axillary vessels are approached by resection of only the central third of the bone.

The patients operated upon varied in age from nineteen to thirty-eight years. Thir-

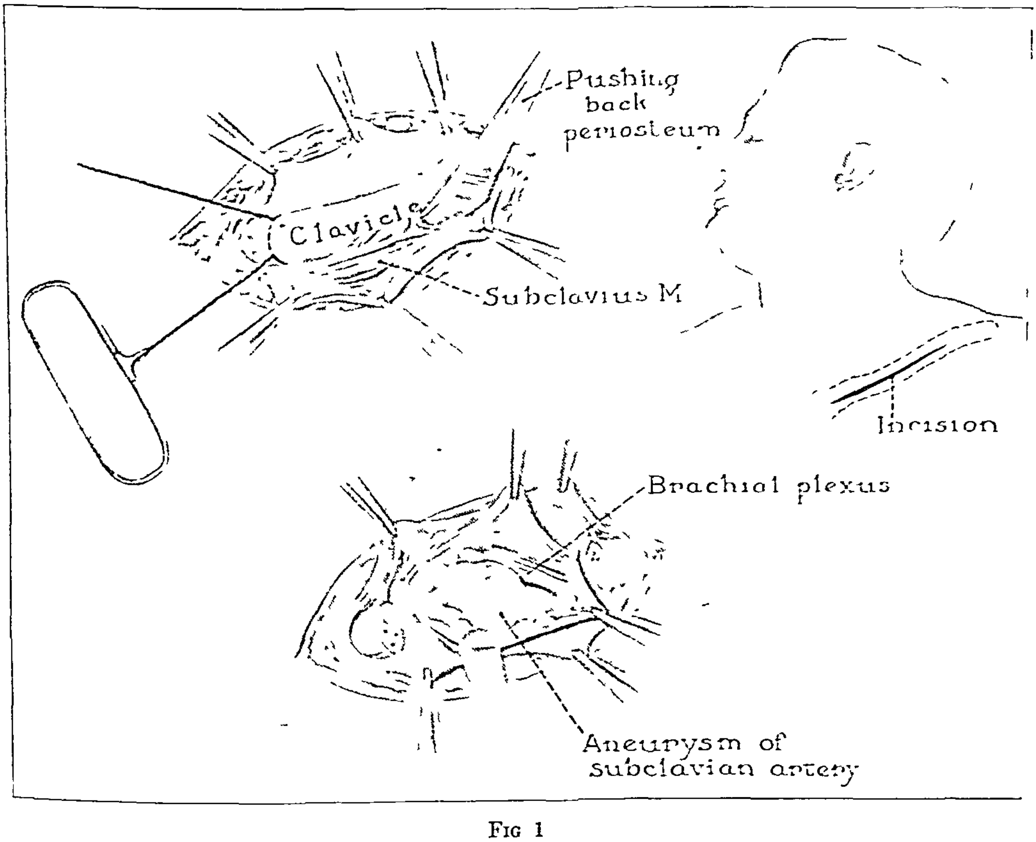

FIG 1

Resection of clavicle for aneurysm of subclavian artery and associated injury to the brachial plexus.

Fig. 2
Resection of clavicle for subclavian aneurysm. Appearance of wound ten days after operation. No deformity.

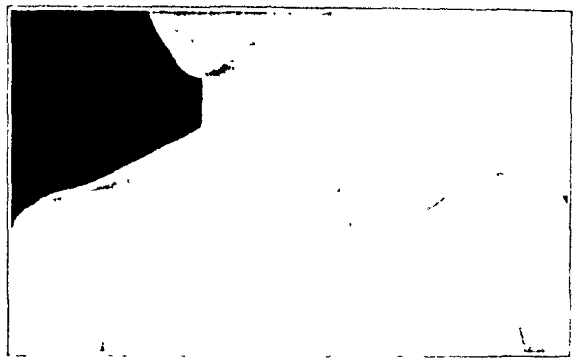

Fig. 3
Resection of clavicle with extension of the incision upward for arteriovenous aneurysm of the internal carotid jugular vessels. Appearance three weeks after operation. No deformity.

Fig. 4
Resection of medial third of clavicle and extension of incision upward for excision of internal carotid jugular arteriovenous aneurysm. Appearance three weeks after operation. No deformity.

Fig. 5
Resection of clavicle and extension of incision outward and downward for excision of axillary arteriovenous aneurysm. Appearance ten days after operation. No deformity.

teen had associated nerve injuries, which were repaired at the same operation. The central portion of the clavicle was resected in thirty-four instances and the medial half, including the sternal articulation, was resected in fourteen cases. In eleven cases the vascular lesion was a false arterial aneurysm, in thirty-five cases it was an arteriovenous communication, and in two cases there was constricting scar tissue about the vessel. The vessels involved are shown in Table I.

TABLE I

Vessels Involved in Resection of the Clavicles

	Number of Cases
Innominate	1
Subclavian	22
Axillary	14
Carotid	5
Vertebral	3
Transverse scapular	2
Transverse cervical	1
Total	48

TECHNIQUE

An incision is made over the most prominent portion of the clavicle to be resected and, if necessary, is extended along the course of the vessels (Figs. 1, 2, 3, and 4). Bleeding is reduced by incising the periosteum on the anterior surface of the bone away from the sites of muscular attachment. The periosteum strips freely, but the transverse scapular vessels run close to the posterior surface of the clavicle and are easily injured if the periosteum is torn. The clavicle itself frequently forms a portion of the arterial false sac;

its removal may be accompanied by profuse bleeding, which must be controlled by digital pressure at the site of the opening. The mobilized portion of the bone is then divided with a Gigli saw and discarded. If the sternal end is removed, the cartilage should be excised. A vertical incision beneath the sternal end will expose the innominate and carotid vessels, and the first portion of the subclavian vessel and its branches. A vertical incision through the central portion of the clavicular bed will expose the subclavian vessels and the brachial plexus. Division of the scalenus anterior muscle facilitates exposure of the first and second portions of the subclavian artery. Development of the interval between the pectoralis major and deltoid muscles, with the cephalic vein as a landmark and with division of the costocoracoid membrane, will greatly increase the exposure, permitting access to the axillary vessels (Fig. 5). Closure of the wound is effected in layers, repairing the periosteum with interrupted fine silk sutures. The excised segment of the clavicle is not replaced. The dressing is enforced with adhesive tape, leaving the arm and forearm free.

RESULTS

There is little postoperative discomfort associated with the procedure, and the patients become active without pain within two weeks. There is little external deformity, and less asymmetry than in instances in which the clavicle is replaced (Figs. 6 and 7). Slight shortening is occasionally noted. Although the regeneration of bone is slow, the area becomes firm within two weeks, with the shoulder girdle adequately fixed. Palpation of the area is deceptive at this time, as the absence of the bone cannot be detected. The patient usually returns to normal activity within six or eight weeks. There was no appreciable difference in the postoperative results in cases in which the articular portion was resected.

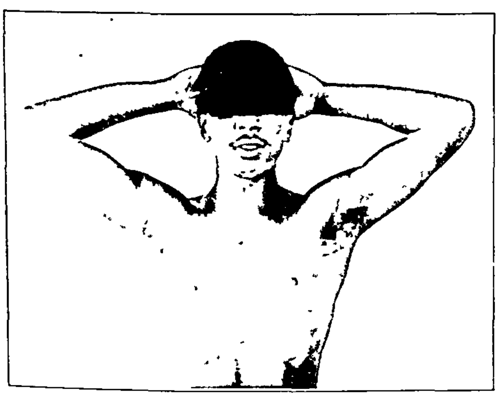

Fig. 6

Resection of inner half of clavicle and portion of sternum for innominate arteriovenous aneurysm. No deformity. Normal range of motion.

Fig. 7

Resection of left clavicle for excision of transverse scapular arteriovenous aneurysm. Appearance two months after operation. Superimposed pictures show range of motion.

Although the function of the clavicle is generally regarded as that of a fulcrum to provide better lateral motion of the arm, its occasional congenital absence is of little if any consequence. In many Carnivora, it is normally rudimentary. Surely it does not regenerate within two weeks after subperiosteal resection, although within that time the arm regains its functional activity. New bone can be palpated within a few weeks, but several months will elapse before it can be demonstrated by roentgenogram.

Note: Resection of the clavicle, as discussed in this paper, is concerned only with the approach to blood vessels. In this Hospital it has been employed in eighteen additional instances in operations upon the brachial plexus. In one other patient a portion of the clavicle was resected because of painful union of a fracture, with subsequent relief of pain and improvement in function of the arm.

TRANSVERSE SACRAL FOLDS *

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Since the introduction of continuous caudal analgaesia into the field of obstetrics by Edwards and Hingson, the topography of the sacrum has merited attention. In recent studies of the anatomical features and structural variations of the sacrum by Trotter and Letterman, ten sacra were encountered which presented bony configurations on the dorsal (or posterior) surface simulating a transverse fold, best marked within the limits of the articular sacral crests, and involving the sacral grooves and median crest.

This paper has as its purpose a detailed description and pictorial presentation of this variation, together with some comments upon its race, sex, and age incidence, accompanying skeletal changes, possible etiological factors, and probable clinical significance.

The original observations were made on 1,227 sacra, of which 553 were male and 674 were female. Of the bones studied, 881 form a part of the Terry Anatomical Collection, Washington University, and 346 are a part of the Todd Anatomical Collection, Western Reserve University. The preparation and methods of documentation of these collections were described by Cobb and by Terry, in 1932.

The following anatomical description of the dorsal surface of the typical sacrum was made by Terry in 1942: "The dorsal surface [facies dorsalis] is strongly convex and rough, giving origin to the powerful sacrospinalus muscle. The midline is occupied by the median sacral crest [crista sacralis media] representing the somewhat suppressed cranial four spinous processes. Of these the first is the largest, the second and third may be confluent, and the fourth is rudimentary. The bone on each side of the median sacral crest is slightly hollowed and is formed by the united laminae. . . . Lateral to the median sacral crest are the paired articular sacral crests [cristae sacrales articulares] representing the articular processes of the movable vertebrae. . . . Immediately lateral to the articular processes are the posterior sacral foramina [foramina sacralia posteriora] (f. s. dorsalia INA), four on each side; smaller than the anterior foramina, they give exit to the posterior primary divisions of the first four sacral nerves and branches of the lateral sacral arteries. . . ."

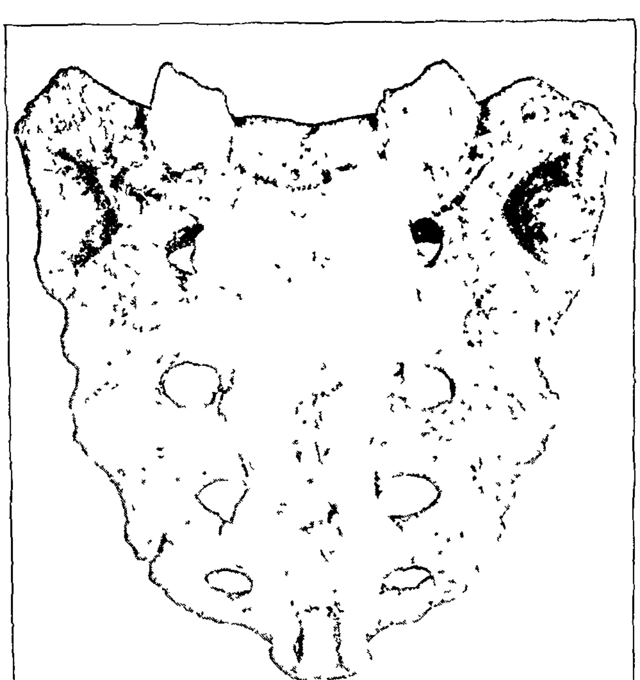

FIG. 1

W. U., No. 686. White female, seventy-eight years of age. Dorsal view of a typical sacrum.

The sacra which present the transverse folds are described individually, and the condition of each skeleton as a whole is noted. For comparison, the dorsum of a typical sacrum may be seen in Figure 1.

Skeleton W. U., No. 480, was of a white female, aged seventy-seven years. The sacrum presented a deep transverse fold at the level of the union of the laminae of the second and third segments (Fig. 2-A). The fold appeared as though the upper or cephalic portion of the dorsum of the bone had telescoped into the lower portion. It was sufficiently deep and depressed to have completely obliterated the lumen of the sacral canal at this level. The second pair of posterior foramina were markedly reduced in size

* Aided by a grant from the United States Public Health Service.

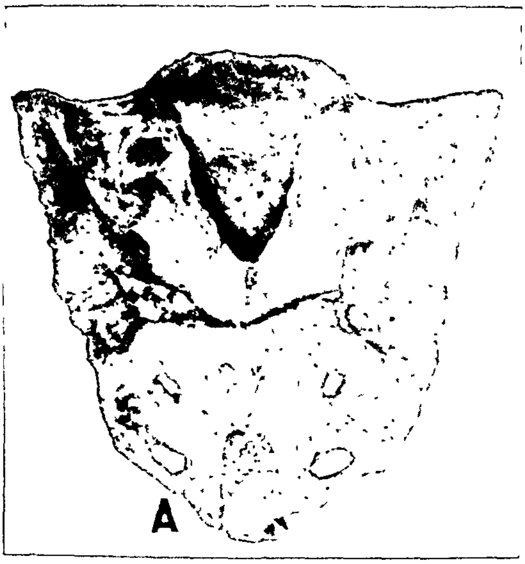

FIG. 2-A
Fig. 2-A: W. U., No. 480 Dorsal view.

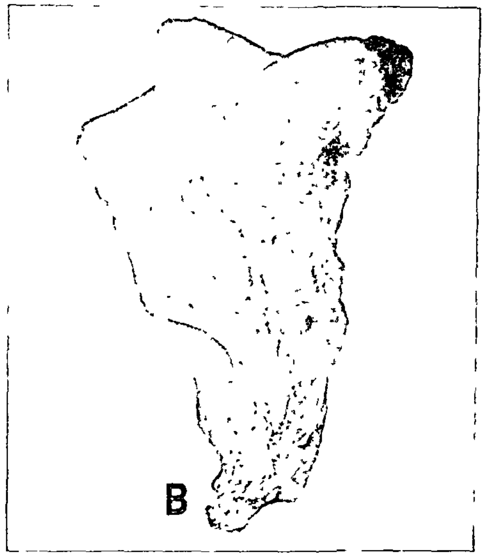

FIG. 2-B
Fig. 2-B: Oblique view of ventral surface.

and showed very irregular circumferences. The tuberosities of the bone were "wrinkled" and presented unusually deep depressions, or fossae. The ventral surface of this sacrum had a sudden concavity forward, beginning at the union of the bodies of the second and third vertebrae (Fig. 2-B). Among the movable vertebrae, marked reduction of the anterior vertical height of the bodies, accompanied by cupping of the superior and inferior surfaces, characterized the sixth, eighth, and twelfth thoracic vertebrae; cupping was also present in the third and fifth lumbar vertebrae. The skeleton in general was somewhat demineralized and porous in texture.

Skeleton W. U., No. 997, was of a white female, aged eighty-eight years. The fold on the dorsum of this sacrum (Fig. 3-A) was at the level of union of the second and third segments, but was much less marked than that of No. 480. It might be described as a transverse sulcus. The second posterior sacral foramina were somewhat reduced; their circumferences were smooth. The ventral surface of the first sacral vertebra and the lateral mass of the second sacral vertebra presented depressions in the sagittal plane (Fig. 3-B). Beginning at the level of the fourth thoracic vertebra, the remaining thoracic vertebrae and the lumbar vertebrae all showed diminution in the vertical height of the bodies, accompanied by cupping of both the superior and inferior surfaces. Both conditions were extreme in the seventh, eighth, and eleventh thoracic vertebrae, and in the third and fifth lumbar vertebrae. (The tenth thoracic and the first lumbar vertebrae were missing.) The centrum of the eighth thoracic vertebra presented a fold in the anterior and lateral parts of its circumference, lying in a transverse plane. There was an unhealed fracture of the neck of the left femur. The entire skeleton was exceedingly porous and demineralized.

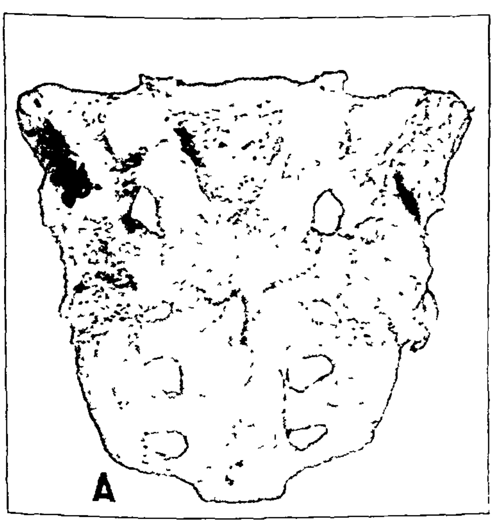

FIG. 3-A
Fig. 3-A: W. U., No. 997. Dorsal view.

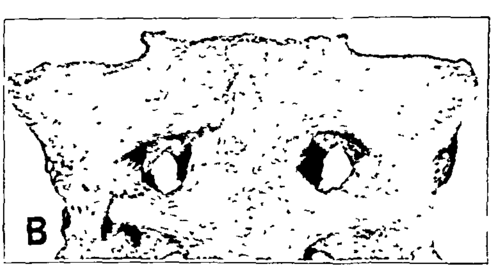

FIG. 3-B
Fig. 3-B: Ventral surface of first two segments.

FIG. 4
W. U., No. 1370. Dorsal view.

FIG. 5
W. R. U., No. 1451. Dorsal view.

Skeleton W. U., No. 1370, was of a white female, eighty years of age. The fold on the dorsum o this sacrum was found at the level of union of the laminae of the third and fourth vertebrae (Fig. 4) The third pair of posterior foramina were reduced in size; the right one was almost obliterated. Th tuberosities showed "wrinkling", and the bone as a whole was very flat. The cervical and thoraci segments of this column, between the levels of the third cervical and the seventh thoracic vertebrae presented lipping of the bodies (this has been described by Hrdlička as one of the natural processes o old age); the third and fourth cervical vertebrae were fused, as were also the fourth and fifth thoraci vertebrae. The left hip bone showed evidence of a healed fracture at approximately the mid-region o the inferior ramus of the ischium. Except for the skull, the skeleton was cinder-like in texture.

Skeleton W. R. U., No. 1451, was of a white female, seventy-five years of age. Two transverse fold were seen in the sacrum (Fig. 5). One lay at the level of union of the laminae of the second and thir vertebrae; the second, which was more of a sulcus than a fold, occurred between the fourth and fift sacral vertebrae. The second and fourth pairs of posterior sacral foramina were markedly reduced i size. The bone was very flat; the dorsal surface was actually concave forward at the level of the uppe fold. The seventh cervical vertebra presented slight lipping. The last four thoracic vertebrae and all o the lumbar vertebrae showed compression of the vertical diameters of the bodies; the lumbar segment

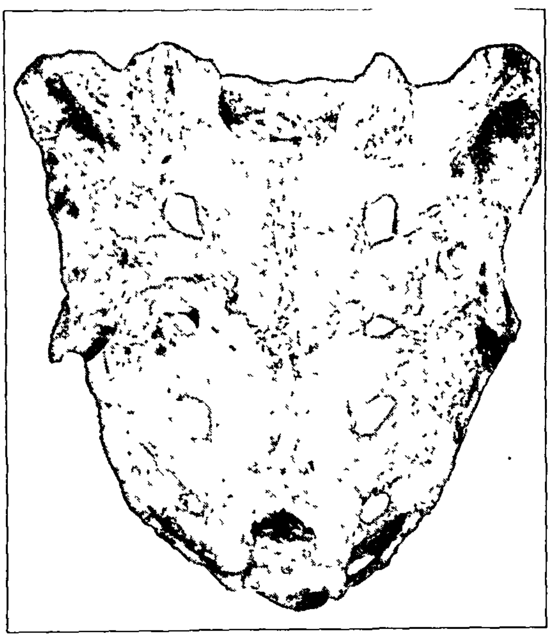

FIG. 6
W. U., No. 1496R. Dorsal view.

FIG. 7
W. R. U., No. 1753. Dorsal view.

FIG. 8
W. R. U., No. 1754. Dorsal view.

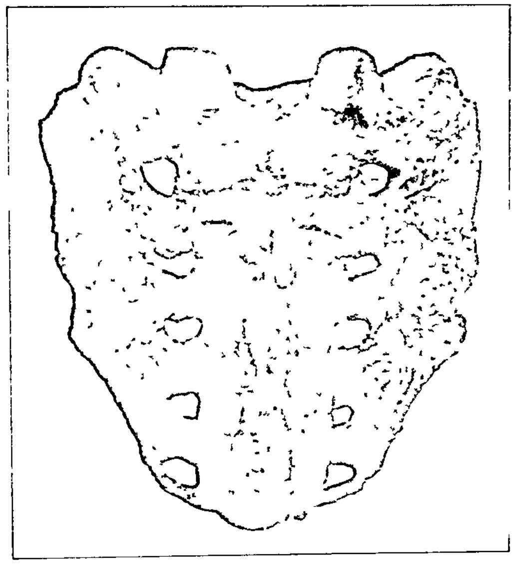

FIG. 9
W. R. U., No 2606. Dorsal view

presented lipping, also. There was an unmended fracture of the neck of the left femur. The skeleton was exceedingly demineralized.

Skeleton W. U., No. 1496R, was of a white female, aged sixty-nine years. The dorsum of the sacrum presented a slight fold at a level between the laminae of the second and third segments (Fig. 6). This fold had the form of having had the upper part of the bone telescoped over the lower part The second pair of foramina were reduced in size. The first coccygeal vertebra had become sacralized. The cervical spine showed lipping. The seventh, ninth, eleventh, and twelth thoracic vertebrae, and the first lumbar vertebra, showed marked reduction in general thickness of the bodies, together with an even greater diminution of the anterior heights. These bones also presented cupping on the superior and inferior surfaces of the centra. The cupped condition could be seen in each of the lumbar vertebrae The left femur showed an unhealed fracture of the neck (with a Smith-Petersen nail maintaining the two fragments in place), and a second unhealed fracture at the level of the junction of the first and second fourths of the shaft. The left hip bone presented a healed fracture at the junction of the body of the pubis with its inferior ramus The skeleton, including the skull, was extremely light and demineralized.

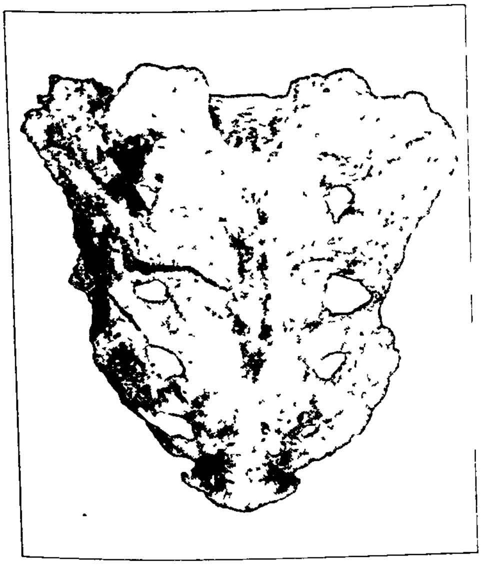

FIG 10
W. R. U, No 2773 Dorsal view.

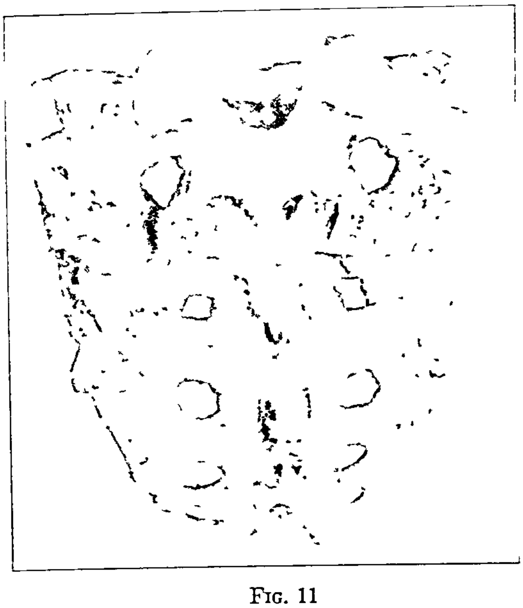

FIG. 11
W. R. U., No. 3099. Dorsal view.

Skeleton W. R. U., No. 1753, was of a white female, eighty years of age. The sacrum had a transverse fold between the union of the second and third laminae (Fig. 7). The second posterior sacral foramina were reduced in size. There was an ovoid aperture on the right side, indicating a deficiency in the union of the first and second laminae. The cervical vertebrae showed marked lipping; this condition was slight in the thoracic region, except for the tenth and eleventh vertebrae, which were fused. Lipping was also slight in the lumbar region, but the bodies of the vertebrae of this segment were compressed, and there was cupping of the superior surfaces of the second, third, and fourth vertebrae. The skeleton was greatly demineralized, and had the cinder-like texture found in old age.

Skeleton W. R. U., No. 1754, was of a white female, eighty years of age. The sacrum was in poor condition; the right joint area and adjoining bone had been broken off and lost. Probably the fragile texture contributed to this accident during the skeletonization process. However, a sulcus was present at the level of the second laminae (Fig. 8). The second foramina, especially the one on the left, were reduced in size. The bone was markedly concave forward on its ventral surface. The movable vertebrae showed nothing of interest. The neck of the left femur had an unmended fracture. In general, the skeleton was fragile and demineralized.

Skeleton W. R. U., No. 2606, was of a white female, aged eighty years. The sacrum was composed of six segments, of which the first showed rather well-marked lumbar characteristics. The fold, which appeared slightly above the level of union of the second and third pairs of laminae, was accompanied by constricted foramina (Fig. 9). The fourth, fifth, and sixth cervical vertebrae had slight lipping, and the anterior margins of the bodies were somewhat compressed. The skeleton was extremely light and demineralized.

Skeleton W. R. U., No. 2773, was of a negro female, sixty-four years of age. The first coccygeal segment was fused to the sacrum. A transverse fold was present at a slightly higher level than the union of the second and third laminae (Fig. 10). The second posterior foramen on the left was reduced and the right one appeared to be enlarged; however, close inspection revealed that the margins had been broken away. The tuberosities were very much wrinkled. On the anterior surface, transverse furrows or sulci were present at the point of union of the lateral parts of the first and second vertebrae,—the usual site of broad grooves occupied by the anterior primary divisions of the first sacral nerves. The sixth to the twelfth thoracic vertebrae showed marked anterior lipping; the seventh, eighth, ninth, and tenth vertebrae were completely fused. The fourth and fifth lumbar vertebrae were fused by ossification of the ligamenta flava. There was evidence of anterior lipping on the fifth lumbar vertebra. The left humerus had been broken in the upper third of its shaft. In general, the skeleton was greatly demineralized, rarefied, and cinder-like in texture.

Skeleton W. R. U., No. 3099, was of a white female, forty-two years of age. The sacrum was composed of six segments, the first of which was the fifth lumbar vertebra. A fold was present at the union between the laminae of the first and second sacral vertebrae (Fig. 11). The first posterior sacral foramina were diminished. The tuberosities presented wrinkling. No unusual features were noted in the movable vertebrae. The skeleton was exceedingly light, demineralized, and cinder-like in texture.

COMMENT

The ten specimens which showed transverse sacral folds were all found in female skeletons. Of the 1,227 sacra studied, 553 were male. Thus, among the female sacra, 1.5 per cent. showed the condition; the occurrence was 3.9 per cent. in 233 white females and 0.2 per cent. in 440 negro females. It is therefore possible that race may be a significant factor. Age also plays an important part since, with one exception (W. R. U., No. 3099, aged forty-two), all specimens were from individuals sixty-four years of age or older. In the series examined by Trotter and Lanier, the ages ranged from fourteen through 101 years, with a fairly even distribution from the third through the eighth decades. There were 194 females who were sixty years of age or older, and 4.6 per cent. of this group presented a transverse fold.

Willis found congenital variations to be quite common in the lumbar and sacral regions of the vertebral column. The fact that all the folds occurred at or near the site of union of two contiguous vertebrae suggests that the folds may be congenital and result from an anomalous development of the segments. On the other hand, the fact that none of the folds were found in a young specimen is equally suggestive that the condition may develop during life. In an effort to find transverse folds in children, 200 roentgenograms of children up to fifteen years of age were examined. They are in the files at Shriners' Hospital, St. Louis, and include a large number which show congenital variations. At the Mallinckrodt Institute of Radiology, 125 roentgenograms of adult sacra were also exam-

ined. These included examples of spina bifida, malignancy, arthritis, and fracture, as well as normal sacra. Nothing resembling a transverse fold was found. No roentgenograms of healed sacral fractures were examined, however; only fresh fractures were included in this series.

Osteoporosis has been shown to be a constant finding in the skeletons described. Black, Ghormley, and Camp, in a comprehensive article on senile osteoporosis of the spinal column, called attention to the fact that the condition is seen approximately four times as often in women as in men. As osteoporosis progresses, the bony trabeculae decrease in number and they are no longer able to support the weight of the body; the vertebral bodies react to this by collapse, and fractures are common. In several of the specimens described in this report the transverse fold could be seen to continue laterally as a line, and on the anterior aspect it included the area lateral to the sacral foramina. However, the median area of the anterior aspect showed no defect. These folds might conceivably represent a buckle type of fracture, occurring in a bone previously weakened by osteoporosis.

Regardless of the etiology, it is possible that these defects may be clinically significant. Sarpyener has shown that sensory and motor changes can arise from congenital narrowing of the vertebral canal. It has also been stated by Bonnin that, following sacral fractures, compression of nerves exiting through the anterior sacral foramina may produce varying degrees of paralysis of the lower extremities. The foramina involved in these cases, however, are the posterior sacral foramina, through which pass the posterior primary divisions of the spinal nerves concerned. These nerves contain motor components which supply the lower autochthonous muscles of the back, and sensory components which, as the medial clunical nerves, supply the skin over the gluteal region. Following compression of these nerves, one might expect consequent sensory changes and slight atrophy of the muscles supplied. The muscle atrophy, however, would be so slight as to be unrecognized, and the sensory changes would very likely be obscured by the symptoms produced by the hypertrophic arthritis and osteoporosis present in these individuals. Case records of four of the individuals from whom these specimens came were available, but they were very brief and contributed no pertinent information.

NOTE: The authors wish to express their appreciation to Normand L. Hoerr, M.D., Professor of Anatomy, Western Reserve University, for the privilege of studying the Todd Anatomical Collection; and to Sherwood Moore, M.D., Director of the Mallinckrodt Institute of Radiology, for the privilege of studying the roentgenograms of adult sacra.

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SPASTIC FLAT-FOOT *

BY PAUL W. LAPIDUS, M.D., NEW YORK, N. Y.

Although the painful condition of the foot, usually diagnosed as "spastic flat-foot", "rigid flat-foot", "contracted flat-foot", or "spasmodic flat-foot", represents a definite clinical entity with sharply defined characteristics, most of the textbooks fail to give a clear description of its symptoms, etiology, and treatment.

REVIEW OF THE LITERATURE

Most investigators seem to believe that this condition is a form or a phase of flat-foot, which became irritated and inflamed as a result of faulty mechanics.

This view was expressed as early as 1883 by Lorenz, who considered "spastic flat-foot" the result of an instinctive, reflex fixation of the irritated, inflamed flat foot in the position in which it is the least painful. Lorenz quoted Roser, who compared the spastic flat foot with fixation of the femur in coxitis. Not every flat foot, according to Lorenz, develops to the phase of "contracted flat-foot". The irritative, inflammatory process not only occurs in the joints, but it must be assumed that traumatic periosteal irritation is also produced. Lorenz was convinced that a flat foot can never be converted into a well-arched foot; and it is even less possible to re-establish a normal shape in an old flat foot. His method of handling this condition was mainly preventive, being instituted before the flat foot became a spastic flat foot (*contracten Plattfuss*). Lorenz noted that the foot of the newborn child is always flat, and the arch develops with growth.

The author's experience has led him to the conclusion, advanced by Lorenz in 1883: "Flat-foot, therefore, may be looked upon as a result of absence of this process of growth and is due to arrest of its development".

Jones and Lovett, discussing flat-foot, state: "Peroneal spasm, as a rule, accompanies the more severe cases. The peroneal tendons will be found contracted and standing out under the skin, the foot is abducted and everted, and attempted correction is painful along the course of the peroneal muscles. . . . Spasm of the extensor·digitorum is sometimes found in addition to that of the peronei." These investigators recommend peroneal tenotomy (devised by Jones), and "an alternative method of eliminating the spasm is to crush the musculo-cutaneous nerve" [17].

Whitman does not describe this condition as a separate ailment. He writes: "Limitation of motion is caused by the changes in structure in accommodation to functional use. These are first evident in muscles, then in the ligaments, and, finally, in the articular surfaces of the bones. Added to this underlying limitation of motion there is usually a certain degree of muscular spasm, which varies in grade with the local congestion, irritation, and inflammation of the joints and tissues."

Whitman defines the extreme deformity of rigid weak foot as one "in which the symptoms are disabling and in which the foot is fixed in the deformed position by muscular spasm and by secondary changes in the structure". He recommends forcible overcorrection of the deformity under anaesthesia and immobilization in a plaster cast, followed by physiotherapy and daily passive manipulations. He states: "Occasionally also in resistant cases division of the peroneal tendons may be advisable."

Dickson and Diveley, discussing the pathology of flat-foot, are no more explicit in describing their observations. They write: "If the causes responsible for pes planus continue active over a long period of time, prolonged irritation of the ligaments and joints of the foot may result in proliferative changes in these ligaments and joints, particularly if an arthritic diathesis is present. Whether a true arthritis develops or the changes in the foot joints are merely those of chronic irritation, the range of motion in these joints is reduced or even lost, and the foot becomes fixed in the position of deformity and a rigid

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pes planus results. With the foot fixed rigidly in pronation and eversion, the peroneal muscles contract and shorten, and so contribute to the rigidity of the foot, and provide an additional check to joint movement. . . ." "In the rigid type of flatfoot, the tendons of the peroneus longus and brevis will be short and contracted, the lateral mobility of the foot will be seriously limited, and it will be impossible to bring the foot into a position of correction."

The treatment recommended by Dickson and Diveley for rigid flat-foot is exactly the same as advised by Whitman: manipulation under anaesthesia, immobilization in a plaster cast, physiotherapy, and passive manipulations. "At times the peroneal tendon and the tendo achillis are so contracted that it is necessary to lengthen these structures by operation before complete correction of the valgus position of the foot is possible."

Lewin, discussing the pathological anatomy of the pronated foot, states: "The peroneal tendons are contracted because they are allowed to shorten." The following method of treatment, attributed to Freiberg, is outlined: In cases of spasm of mild degree, adhesive strapping is used and "should be continued until it is possible to bring the foot into supination". This is supplemented with "injection of a few drops of a 5 per cent novocain solution into the astragalo-navicular joint". "For cases in which peroneal spasm is too rigid to yield to these simpler methods", resection of peroneal tendons "with subcutaneous division of the tendon of the extensor communis digitorum muscles" is advised. "In cases of rigid flat-foot, forcible manipulation under anesthesia and the application of a corrective plaster cast are of great value. Occasionally, the peroneal tendons must be resected."

Weil does not agree with the prevailing conception of the reflex origin of muscle spasm in contracted flat-foot, caused by irritation of the subtalar joint subsequent to abnormal position of the bones. In two of his cases, he attempted to freeze the peroneal and tibial nerves above the ankle after these nerves had already given off their motor branches to the leg muscles, thus interrupting chiefly the sensory branches to the ankle and foot joints. The muscle contraction disappeared during the operation while the patients were under anaesthesia, but the painful spastic flat-foot recurred after the operation in both cases. Hence came Weil's theory of "proprioceptive reflex", which he believes is caused by changes in the muscles themselves, but not from irritated foot joints. Weil's two cases are not at all convincing. He does admit in his conclusion that the whole problem is not clear, since only a few patients with flat-foot ever develop spastic flat-foot. Likewise, it is not clear to him why spasm does not occur also in pes varus. The latter question seems to be an important one and will be discussed later.

Haberler and Winkler also refuse to accept the theory of formation of spastic flat-foot from a flaccid flat foot as a result of faulty mechanics, caused by inward and downward displacement of the talus against the calcaneus, the thrust of the talar head producing strain of the medial ligaments and irritation of the talonavicular joint, which in its turn induces a cramplike reflex muscle spasm. They quote Lorenz's attempt [12] to prove experimentally the theory of reflex spasticity by relieving the muscle spasm, after injecting novocaine into the talonavicular joint in cases of spastic flat-foot. This has been looked upon as interruption of the reflex arc.

According to Haberler and Winkler, this theory of reflex spastic flat-foot has been almost unanimously accepted, although various locations of the irritation causing the spasm have been considered by different writers.

Payr claimed the irritation to be mainly of the posterior chamber of the subtalar joint; Hoffa localized it in the talonavicular ligament, while Hohmann and also Port held that the irritation of the synovial lining and of the periosteum of the Chopart joint was responsible for the initiation of the reflex chain leading to the spasm.

Haberler and Winkler bring out the point that the spasticity occurs almost exclusively in the pronators (chiefly the peroneal muscles). They assume that the medial structures of the talonavicular joint must be the ones that are mainly irritated by the

medial and downward thrust of the talar head in a flat foot. Consequently, they would expect the supinators of the foot to become spastic and not the pronators. Therefore, they cannot agree with the reflex origin of the muscle spasm in spastic flat-foot. In 28 per cent. of their cases, Haberler and Winkler found evidence of psychic and somatic "degenerative changes" with signs of disturbance of the pyramidal tract. Hyperflexion was almost always noted in their patients, and out of a total of forty-two cases of idiopathic spastic flat-foot, positive Babinski reflex or Oppenheim's sign was obtained in ten cases. Haberler and Winkler conclude that spastic flat-foot only rarely occurs from flaccid flat-foot, and explain the origin of the "idiopathic muscle-bound flat foot" as a lesion of the central nervous system.

Although the work of these investigators gives the impression of being quite thorough and complete, their neurogenic theory seems to be too artificial and speculative, and has not been corroborated by other observers.

Little can be found on the subject in Hohmann's book on the foot. He devotes no separate discussion to spastic flat-foot and essentially agrees with the accepted theory of causation of the contracted flat foot. He brings out the fact that the tibialis anterior may become converted from a supinator into a pronator of the foot, as the result of marked abduction of the forefoot in flat feet (Fig. 3-A). In such cases the tibialis anterior and the peronei may be found spastically contracted, and may cause a dorsiflexion contracture of the foot combined with valgus. Hohmann advises against forceful manipulations in rigid flat-foot and considers interruption of the peroneal nerve an irrational procedure, since "the cause of the pronator's spasm lies not in the muscles themselves, but in the process of deformation of the flat foot".

Malkin defines spasmodic flat-foot as "a condition in which the foot, without evidence of a bony lesion, is held in a valgus position by spasm of the peronei".

According to Fick, the invertors of the normal foot are stronger than the evertors. Therefore, if there were any lesion of the subtalar or midtarsal joint, the foot must be expected to assume an inverted (varus) position as a result of a protective spasm of all its muscles.

Testing the relative strength of the invertors and evertors, Malkin found that in a group of patients undergoing treatment for flat-foot, the above normal relation was reversed, the evertors becoming stronger. Therefore, Malkin concludes that in flat-foot the invertors become relatively weaker and, if "there were a lesion of the subastragaloid and midtarsal joints, protective spasm might be expected to hold the feet not in inversion, but in eversion".

In a discussion of Malkin's paper, Brockman reported disappointing results in his cases, and pointed out that: "In those in which the peronei had been divided, no permanent benefit resulted compared with the others."

Trethowan, also discussing Malkin's paper, stressed the view that "spasmodic flat-foot had nothing really to do with flat-foot". He blamed infectious astragaloscaphoid and subastragaloid arthritis for causing spastic flat-foot, and called it "tonsil flat-foot". Except for early cases, he considered the condition incurable. He abandoned manipulations and used only rest and support for the feet.

Todd, in a very frank paper, said: ". . . the most I can hope to do is to give a concise summary of the present state of our ignorance". After reviewing the literature on the subject, the writer shares entirely Todd's disappointment, which he expressed as follows: "Not much is to be gained by a perusal of recent surgical literature on this subject." The textbooks "merely present a vague unhelpful description of what they call 'rigid flat-foot' ".

Likewise, Todd's dissatisfaction with the present-day methods of treatment so clearly voices the author's feelings that it is best given verbatim: "In acute spasmodic valgus, therefore, we must not treat the spasm only: that is not the disease, but the result of the

disease. For that reason I regard tenotomy and excision of the peroneal tendons as being based on an entire misconception. And everyone knows that, as a matter of fact, these operations are often unsuccessful, and prone to be followed by reappearance of the pain and deformity. Seeing that the primary cause of the condition has been left unaffected, this is not surprising. Paralysing the peroneal nerve or its musculo-cutaneous division with novocain or alcohol, or crushing it or freezing it, abolishes the spasm for a time but does not remove its cause."

Todd believes that treatment by manipulations and immobilization in varus is not rational and should not be used. He discusses the possibility of eversion of the foot as being the position "of rest or relaxation, in which the joint surfaces on the inner border of the foot are held apart and the joints themselves are in their position of greatest capacity". Therefore, he prefers to immobilize the foot without correction of valgus, which might be physiological in this ailment.

Thus the reflex origin of spastic flat-foot has been recognized for more than half a century, and has been described in all recent textbooks. However, no clear understanding of the exact location and the mechanics of the irritating moment has as yet been reached, as can be judged from the variable interpretations of the origin of the irritation, given by different investigators. In spite of this rather unsettled state in regard to the etiology of the condition, most of the therapeutic procedures seem to be quite uniformly aimed at interruption of the reflex arc. Manipulations under anaesthesia and immobilization in a plaster cast with correction of the valgus deformity, followed by repeated manipulations and physiotherapy, still remain the up-to-date standard methods of conservative treatment.

Resection of peroneal tendons[8], intramuscular infiltration of peroneal muscles with novocaine, or induction of peroneal nerve palsy by freezing the nerve, intraneural injections of novocaine or alcohol, operative crushing of the nerve[17], or by means of a special brace causing pressure and crushing of the peroneal nerve[10] have been advocated as more radical procedures by different writers. However, those who followed their cases long enough and well enough had to admit not only their frequent failures to relieve the original ailment, but also the harmful complications occasionally produced by too radical and not quite sound surgery (for instance, the production of a lasting peroneal paralysis in one of Lilienfeld's cases).

Summarizing our review of the literature, we note that there are certain clinical features which have been agreed upon by all writers on this subject, while other characteristics of the spastic flat-foot have been described only by a few and were variably interpreted by them.

The following clinical features of the so-called spastic flat-foot are unanimously accepted by all observers:

1. It is a painful condition of the foot and ankle, associated with spasm always limited to the pronators (evertors) group. Chiefly the peroneal muscles, sometimes the long extensor of the toes, occasionally also the anterior tibial muscles are contracted, all acting as pronators.

2. Trauma or occupational strain seems to be recorded in an appreciable number of cases.

3. The onset of the condition has been noted most frequently during adolescence.

4. Only a relatively small percentage of cases of spastic flat-foot were noted, in proportion to the very much larger number of flaccid flat feet seen in clinics.

The following clinical characteristics have been variably interpreted:

1. Most of the writers, as the name "spastic flat-foot" itself implies, find evidence of pes planus in addition to valgus position of the foot.

2. On the other hand, a few other observers note a definitely normal or even exaggerated longitudinal arch (pes cavus), with the foot being held in valgus position by the spasm of the evertors.

3. The majority of writers consider the spastic flat-foot as a phase of flaccid flat-foot; a few refute any connection between *flaccid* and *spastic flat-foot*.

4. The pain and tenderness have been noted by the majority of investigators on the lateral aspect of the foot (calcaneocuboid joint, subtalar joint, sinus tarsi). A few observers localized it also over the medial aspect of the foot, mainly at the talonavicular joint.

5. Some observers consider the irritation of the talonavicular or calcaneocuboid, or subtalar (posterior chamber) joint to be due to static and mechanical distortions in flat-foot, being careful to differentiate the "idiopathic spastic flat-foot" from an arthritic one. Others also include in their series the arthritic cases and consider infectious arthritis of these joints as a primary cause of the whole condition (Trethowan's "tonsil flat-foot").

ANATOMY AND MECHANICS OF THE SUBTALAR JOINT

The most important question is why the pronators of the foot are the only muscles which have consistently shown an exclusive tendency to become "spastic".

Why has a similar spasticity never been noted in the supinators group?

Why has muscle spasticity never been associated with the varus (inversion) deformity of the foot?

The answers to these questions and clarification of the entire problem of the so-called spastic flat-foot may be found in the rather complicated anatomy and even more complicated mechanics of the subtalar joint.

The subtalar joint, often called the lower ankle joint or articulus talotarsalis, is a complex articulation between the talus (above) and the calcaneus and the navicular (below). An important structure of the subtalar joint is the interosseous talocalcaneal ligament. The fibers of the ligament run in an almost vertical direction, attaching themselves to the roof and the floor of the tarsal canal (sinus tarsi). The latter is formed by the adjacent deep grooves on the lower surface of the talus (sulcus tali) and the upper surface of the calcaneus, the sulcus calcanei (Figs. 1-A, 1-B, and 2).

The tarsal canal (sinus tarsi) runs obliquely forward and laterally; it is funnel-shaped, being wider laterally. The interosseous talocalcaneal ligament, filling the tarsal canal, likewise runs obliquely forward and laterally across the long axis of the foot (Figs. 1-A, 1-B, and 2). Thus this ligament forms a transverse vertical partition, dividing the subtalar joint into two completely separate chambers: the posterior chamber or articulus talocalcanea, and the anterior chamber or articulus talocalcaneonavicularis (Figs. 1-A and 2). Although anatomically these two articulations are entirely separate, functionally they represent one inseparable unit, since they can move only together and only against the same axis of motion (Figs. 1-A, 1-B, and 3-A). In this respect they can be roughly compared with two hinges of a door, which, although separate, yet always move together.

The motions of the subtalar joint consist mainly of supination (inversion) and pronation (eversion). In addition, supination is combined with some adduction and plantar flexion, while slight abduction and dorsiflexion occur simultaneously with pronation of the foot in the subtalar joint. The axis of motion of the subtalar joint runs slightly obliquely from the dorsomedial surface of the neck of the talus posteriorly, downward, and lateralward, emerging through the lateral posterior surface of the calcaneus (Figs. 2 and 3-A).

The subtalar joint possesses an unusual stability. Dislocation in this joint unassociated with a fracture is very uncommon. This is due mainly to two factors:

1. The alternating shape of the articular facets which are of ball-and-socket type, in both the anterior (talocalcaneonavicular) and the posterior (talocalcaneal) components of the subtalar joint (Figs. 1-A and 2). The upper articular surface of the talocalcaneal joint, supplied by the posterior articular facet of the talus, is concave; while below, the

corresponding posterior facet of the calcaneus is convex. The reverse relation exists anteriorly in the talocalcaneonavicular joint. Here the lower articular surfaces (calcaneus and navicular) are concave, while the upper articular surface (head of the talus) is convex (Figs. 1-A and 2).

2. The interosseous talocalcaneal ligament, firmly binding together the talus and the calcaneus.

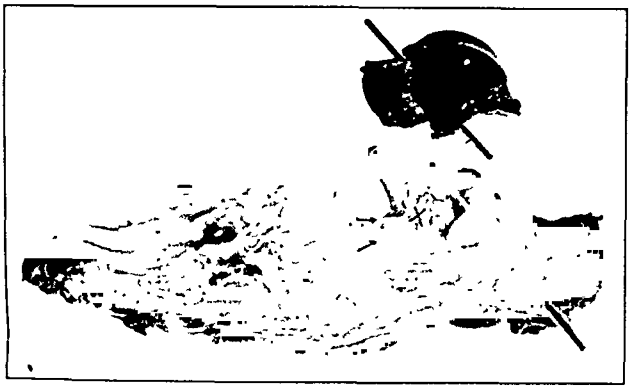

FIG. 1-A

FIG. 1-B

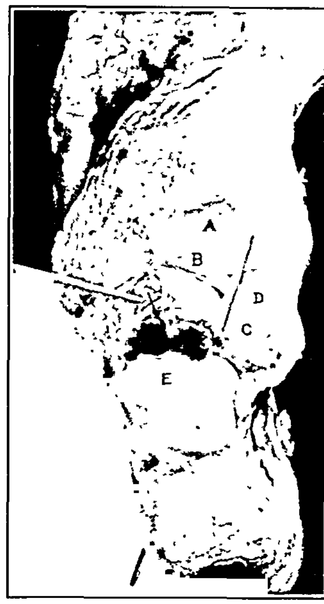

FIG. 2

Fig. 1-A: Left foot viewed from fibular side and also slightly from above. Talus removed, showing the subtalar joint divided almost transversely by interosseous talocalcaneal ligament into two completely separate chambers: the anterior chamber, articulatio talocalcaneonavicularis and the posterior chamber, articulatio talocalcanea. The wooden applicators inserted through the talus and the calcaneus represent the axis of motion of the subtalar joint. Note that the interosseous talocalcaneal ligament is stretched between the sulcus calcanei (below) and the sulcus tali (above), both of these sulci forming the tarsal canal (sinus tarsi). Note also the alternating shape of the articular facets of the anterior and posterior chambers. In the anterior chamber, the head of the talus is ball-shaped and the navicular with the anterior and the middle facets of the calcaneus form the socket; in the posterior chamber the reverse relations are present, the talus is concave, and the calcaneus is convex.

Fig. 1-B: Fibular view of the same foot with the talus replaced. Note that the interosseous talocalcaneal ligament is most accessible to palpation over the fibular side at the sinus tarsi. *X* denotes the interosseus talocalcaneal ligament. Arrows show the pars calcaneonavicularis and pars calcaneocuboidea ligamenti bifurcati.

Fig. 2: The anterior and posterior chambers of the subtalar joint (left foot) viewed from above after removal at the talus. Wooden applicator inserted through the calcaneus represents the axis of subtalar joint motion which crosses the interosseous talocalcaneal ligament (*X*) under right angle, as shown by a toothpick inserted into this ligament from the fibular side. This ligament acts as a partition between the anterior and the posterior chambers of the subtalar joint. The tarsal canal, in which the interosseous talocalcaneal ligament stretches itself, is funnel-shaped, being wider on the fibular side and tapering toward the tibial side just behind the sustentaculum tali. The tarsal canal and also the ligament run obliquely anteriorly and fibulaward, forming an obtuse angle with the longitudinal axis of the foot (running along the second metatarsal).

A. Navicular facet for the head of the talus.
B. Anterior facet of calcaneus.
C. Middle facet of calcaneus over sustentaculum tali.
D. Plantar calcaneonavicular ligament, forming the floor of the anterior chamber of the subtalar joint.
E. Posterior facet of calcaneus (accidentally fractured).

3. Tendons and other ligaments stretching themselves over the subtalar joint.

Figure 3-B illustrates the ligamentous apparatus of the ankle. The head and the ne of the talus have been removed in order to expose the interosseus talocalcaneal ligame and show its relation to the axis of motion of the subtalar joint. It is apparent that the i terosseous talocalcaneal ligament becomes tense on supination (inversion) and is relaxed pronation (eversion), since this ligament is located entirely on the fibular side of the ax of motion. This point is further brought out on Figures 3-D and 3-E, showing the san specimen with the foot held in extreme inversion (Fig. 3-D) and in complete eversi (Fig. 3-E).

These anatomical considerations have furnished us with a definitely established fa in the mechanics of the subtalar joint,—namely, that pronation (eversion) of the foot r moves the tension from the interosseous talocalcaneal ligament; in other words, the pos tion of greatest relaxation in the subtalar joint is that of complete pronation (eversion with the heel held in valgus.

This fact seems to give adequate explanation of the questions enumerated, which th far have remained unanswered or have been variably interpreted by previous invest

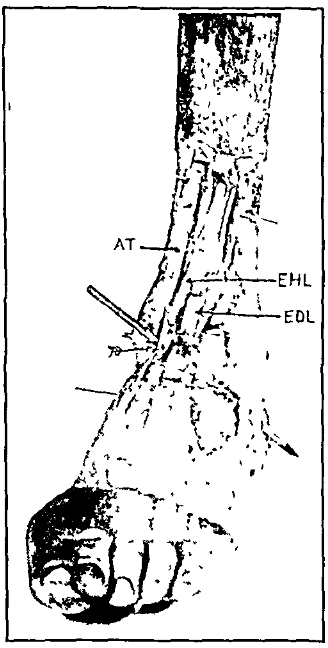

Fig. 3-A

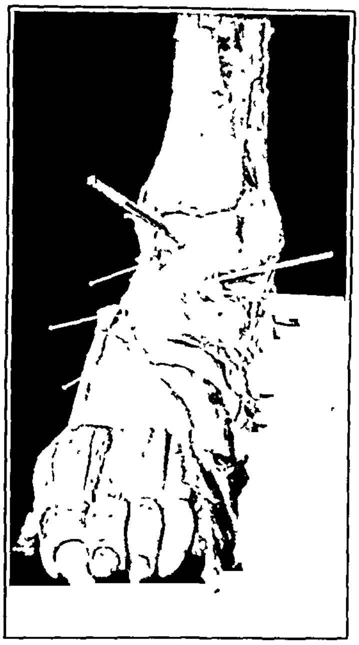

Fig. 3-B

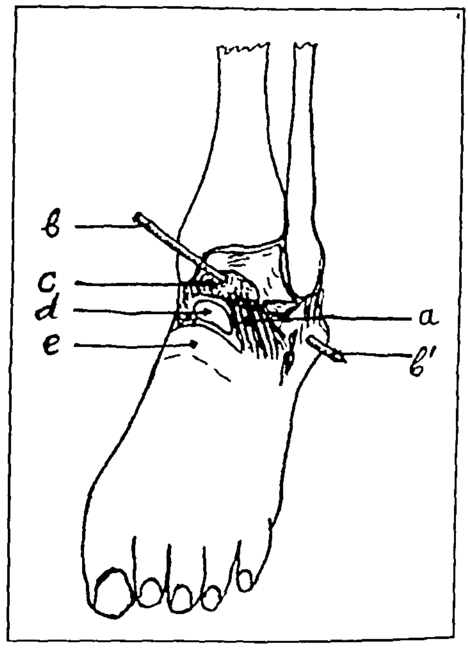

Fig. 3-C

Fig. 3-A: Left ankle and foot with nail representing axis of the subtalar-joint motion. This axis runs from the tibial side, from anteriorly and above toward the fibular side, posteriorly and downward, and does not correspond with the longitudinal axis of the foot (Fig. 2). Note that the axis of subtalar-joint motion passes right through the anterior tibial tendon (*AT*), spit longitudinally over the nail at small arrow. Therefore, in the neutral position of the subtalar joint the anterior tibial is a pure dorsiflexor of the foot, possessing no everting or inverting component. With the foot in inversion (supination), the anterior tibial tendon slips slightly tibiaward to the axis of the subtalar-joint motion; therefore, this muscle also becomes a slight invertor of the foot. When the foot is in eversion (pronation), the anterior tibial tendon slips fibulaward to the axis and consequently becomes a slight evertor of the foot. The extensor hallucis longus (*EHL*) and even more so, the extensor digitorum longus (*EDL*) run fibulaward to the axis of subtalar-joint motion, and therefore act as evertors (pronators) assisting the peroneals.

Fig. 3-B: Same foot, held in neutral position. The talocrural joint is exposed. The head and the neck of the talus have been removed, exposing the anterior chamber of the subtalar joint. Two toothpicks have been inserted into the interosseous talocalcaneal ligament. Note that this ligament is located fibulaward to the axis of the subtalar-joint motion (represented by the nail) and the main part of the ligament is quite a distance away from the axis.

Fig. 3-C: Shows schematically the details of Fig. 3-B.
a. Interosseous talocalcaneal ligament (the toothpicks are not shown).
bb'. Axis of subtalar-joint motion.
c. Rough bone surface of the talar neck, after removal of its head.
d. Floor of the anterior chamber of the subtalar joint.
e. Navicular.

FIG. 3-D

The same specimen with the foot in extreme inversion (supination). Note the wide separation of the toothpicks, proving that the interosseous talocalcaneal ligament becomes tense on inversion.

FIG. 3-E

Demonstrates complete relaxation of the interosseous talocalcaneal ligament on extreme eversion (pronation), the two toothpicks becoming closely approximated and parallel to each other.

gators. It certainly appears to provide a logical explanation for the exclusive tendency of the pronators to become spastic. Likewise, the tenderness over the sinus tarsi (the most accessible region of the interosseous talocalcaneal ligament) and over the subtalar joint itself can now be understood (Fig. 1-B).

DISCUSSION

Thus we may assume that any lesion of the interosseous talocalcaneal ligament, whether of traumatic or inflammatory origin, may produce the symptom complex of so-called spastic flat-foot. The interosseous talocalcaneal ligament is really a part of the subtalar joint, just as the two crucial ligaments are part of the knee joint; consequently, any lesion of the interosseous talocalcaneal ligament, with or without involvement of the entire subtalar joint, may bring about a typical clinical picture of pronators' spasm.

It should be mentioned in passing that a large number of cases observed by the writer not only failed to show any evidence of flattening of the longitudinal arch, but occasionally presented a definite cavus deformity. This was also noted by Haberler and Winkler.

It is true that in a few cases of flat-foot, spasticity may develop, but the percentage is very small, as has been pointed out by several other writers. It is possible that the percentage of feet with a normal arch, in which the spasticity syndrome develops, is just as great as that of flat feet which become spastic. The valgus position of the foot is misleading, and often is misinterpreted as flat-foot, although the longitudinal arch is normal or even exaggerated. Hence the term "spastic flat-foot" seems to be a misnomer and inappropriate, because more often than not there is no flat-foot.

"Spastic subtalar lesion" or "subtalar arthritis with spasm of the pronators" would seem to be better designations.

Spastic subtalar lesion is a symptom complex which obviously may result from various etiological conditions. First will be discussed the cases which have been classified by

some writers as "idiopathic spastic flat-foot". The typical symptoms seemed to develop in these patients spontaneously without any definite etiology of the condition. These cases may be divided into three groups, according to the extent and gravity of the pathological changes.

To the first group belong early cases of adolescent patients with no history of previous episodes. As has already been stated, the feet may be normally shaped (no flat-foot). History of trauma or of an occupational strain can be obtained in a majority of these cases. In sleep or if the patient is given local or general anaesthesia, the spasm of the pronators is entirely relieved. Infrequently, after mere rest in bed for a few days, all the symptoms may disappear. Early diagnosis and complete bed rest, followed by guarded activities and watchful observation, may prevent any further recurrences. Well-fitted metal foot plates and shoes may be helpful.

To the second group belong more advanced cases, with apparently fibrous periarticular changes, since there is absence of subtalar mobility even under general anaesthesia when the spasm of the pronators is completely eliminated. History of previous attacks of pain and spasticity may be obtained in some of these cases. The roentgenograms of the foot fail to show any bone changes. This group presents a more serious therapeutic problem. If rest treatment as suggested for the first group is not successful, sometimes gentle breaking of fibrous tissues by manipulation of the subtalar joint under general anaesthesia, followed by prolonged rest with physiotherapy and immediate active and passive exercises, may relieve the pain and spasm and even enable the patient to resume his work. Post-operative immobilization in plaster should not be employed, since it may bring about the recurrence of fibrous changes. It is doubtful, however, that complete restoration of subtalar mobility will be obtained in the majority of these cases. Recurrence of episodes of pain and spasm of the pronators may be anticipated, especially after overwork. Metal foot plates are helpful, even if the longitudinal arch is normal. Change of occupation to less strenuous work should be given serious consideration.

The third group includes inveterate cases, often patients with a history of several acute attacks and occasional pain and stiffness after overuse of the foot during the quiescent stage. Roentgenograms in these cases show more or less advanced productive osteo-arthritic changes, mostly over the adjacent surfaces of the talus and the navicular and often over the talocalcaneal and calcaneocuboid joints. During the periods of acute exacerbation the pronators become spastically contracted, the foot is painful, and there is periarticular subtalar tenderness most frequently over the sinus tarsi laterally, just in front of the lateral malleolus, sometimes also medially around the sustentaculum tali and just posterior to it (Fig. 2). Occasionally there is tenderness around the talonavicular joint. The heel is held in valgus, and any attempt at passive inversion produces pain. After rest, the spasm of the pronators may disappear, and acute pain and tenderness may be relieved, but the heel may still remain in valgus, and there will be considerable or even complete loss of subtalar mobility. Attempts at inversion of the heel still may be slightly painful, and some tenderness may be obtainable even during the apparently quiescent stage. Obviously therapy in this type of foot is rather limited, and should be directed toward prevention of acute episodes and alleviation of pain during the quiescent stage, in order to enable the patient to do some work, preferably without putting any excessive strain on his feet.

There has been a great deal of prejudice against the use of metal plates in this type of foot with its tarsal joints "rigid" because of secondary osteo-arthritic changes. It has been stated often that, in a "rigid" foot, rigid metal plates are contra-indicated, since the patient will not be able to wear them. Exactly the reverse conclusions seem to be justified from the author's experience.

Well-fitted plain metal plates (Schaffer's type) have been found extremely useful in these patients. It must be emphasized, however, that meticulous care should be exercised

in taking a cast (plaster boot) for these plates. While a foot with movable joints may sometimes adapt itself to an imperfectly fitted plate, a "rigid foot" requires a perfect fit of the plate to the foot. That may be the reason that many of these patients have discarded plates which they have been unable to wear, and yet frequently obtain a great deal of comfort when given a pair of well-fitted rigid metal plates, and often are actually unable to walk without them.

The author has been using exclusively rigid metal plates, since the non-rigid type, as a rule, failed to bring adequate relief. Evidently, only a rigid metal foot plate can provide enough bracing for the osteo-arthritic tarsal joints, just as only a rigid brace can adequately immobilize an osteo-arthritic knee.

In a very few obstinate cases with persistent disability, one may consider fusion of the entire subtalar joint, possibly combined with calcaneocuboid fusion. The writer is opposed to any extensive wedge resections of these joints, and prefers merely a shaving off of the articular cartilage without distorting the configuration of the joint surfaces. The cartilage can also be shaved off from the talar head and the navicular bone without resection of the talar head. The heel should be immobilized in a neutral position. Although some relief may be anticipated after this operation, the foot is far from being perfect and, therefore, the operation should be considered only reluctantly as a last resort in obstinate cases. As a rule, conservative methods patiently adhered to will bring enough relief and in the long run are better than the operation.

The symptoms of spastic subtalar lesion may develop in cases of rheumatoid arthritis. The inflamed subtalar joint is held in pronation in order to secure complete relaxation of the interosseous talocalcaneal ligament. Fibrous changes and often osteo-arthritic manifestations with limitation of subtalar mobility are the usual late results in these cases. The therapy in this type of case is essentially the same as in the idiopathic group. Prevention of valgus deformity by immobilization of the foot in neutral position should be considered before the onset of ankylosing changes. For obvious reasons, cases of fracture of the tarsal bones penetrating into the subtalar joint with lesion of the interosseous talocalcaneal ligament may also present the spastic symptom complex.

All the above considerations seem to furnish reasonable proof that any lesion of the interosseous talocalcaneal ligament may lead to a secondary protective spasm of the pronator muscles, in order to ensure complete relaxation of this ligament. There is no justification for the assumption that the spasticity is a result of primary changes in the pronator muscles [21] or is due to a lesion of the pyramidal tract[5]. Consequently, any operations designed to eliminate the action of the pronator muscles, such as resection of their tendons or induction of their palsy by any methods, should be strongly condemned as unsound, useless, and often harmful, since they are aimed to relieve the consequence without removing the cause of the condition.

No one would consider tenotomy of the hamstrings or crushing of the sciatic nerve, in order to relieve the protective flexion of the knee due to a lesion of its crucial or collateral ligaments. Yet a somewhat similar operative approach is still a standard procedure in the treatment of the so-called spastic flat-foot, and is recommended in textbooks.

It is the hope of the writer that he has given a logical explanation of the mechanics of the condition, now labeled "spastic flat-foot" and has pointed out the irrationality of standard surgical procedures employed in its treatment.

SUMMARY AND CONCLUSIONS

1. A review of the literature on the so-called "spastic flat-foot" shows variable, often contradictory, theories concerning its etiology and treatment.

2. The prevailing conception is that it is a reflectory spasticity of the pronators, which develops in a flaccid flat foot as a result of irritation of the tarsal joints, attributed to faulty statics and mechanics.

3. No satisfactory explanation for the fact that the spasticity is always limited exclusively to the pronators can be found in the literature, although various theories have been advanced.

4. The accepted standard treatment of the so-called spastic flat-foot has been rest, immobilization, physiotherapy, manipulations, resection of peroneal tendons, or even induction of palsy of the pronators by interruption of conductivity of the peroneal nerve by means of injections or crushing of the nerve.

5. A review of the anatomy and mechanics of the subtalar joint shows that the interosseous talocalcaneal ligament is relaxed in pronation, and becomes tense in supination of the foot.

6. The author's theory of the cause of so-called spastic flat-foot as a lesion of the interosseous talocalcaneal ligament or of the subtalar joint with reflex spasm of the pronators to produce relaxation of the above ligament is given.

7. The syndrome of spasticity of the pronators is not peculiar to flat-foot, but is often observed in normal feet or even in cases of cavus. Therefore, the terms, "spastic subtalar lesion" or "subtalar arthritis with spasm of the pronators" are offered as more appropriate designations than "spastic flat-foot".

8. A classification of cases with the method of treatment employed by the author is described.

9. The lesion of interosseous talocalcaneal ligament is the primary cause, and spasm of the pronators is the consequence. Therefore, any operations designed to eliminate the action of the pronator muscles (tenotomy or interruption of peroneal nerve) are strongly condemned as being unsound, futile, and often harmful.

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BACTERIOLOGICAL EXAMINATION OF THE GASTRIC CONTENTS IN THE DIAGNOSIS AND MANAGEMENT OF TUBERCULOSIS OF THE BONES AND JOINTS

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A substantial percentage of patients with active pulmonary tuberculosis, particularly infants and young children, do not expectorate, and consequently no sputum is available for bacteriological examination. The fasting gastric contents of more than 2,000 patients with pulmonary tuberculosis have therefore been examined for the presence of tubercle bacilli. In this group of cases the procedure has served as an indispensable criterion for the identification of active disease, and has been carried out either at the time of the diagnostic survey of the patient or during the course of treatment by bed rest or by pulmonary collapse.

Since 1898, when Meunier first advocated this diagnostic method, a number of publications have confirmed its usefulness. Most of the available reports, however, deal with its applicability in parenchymal pulmonary tuberculosis and in tuberculosis of the hilar lymph nodes. In patients with parenchymal pulmonary tuberculosis who do not expectorate or who have negative sputum, tubercle bacilli were found in the gastric contents in 60 per cent. of the cases of Gad, in 55 per cent. of Gullbring and Levin's cases, and in about 20 per cent. of the cases of Ulmar and Ornstein. In children with pulmonary tuberculosis (parenchymal or hilar), Opitz found tubercle bacilli in the gastric contents in 93 per cent., Boer in 73 per cent., and Langer in 40 per cent., as quoted by Dietzel.

These results suggested the possibility that examination of the fasting gastric contents might be of value in the diagnosis of patients suspected of having tuberculosis of the bones or joints. While early recognition of these cases is of the utmost importance from the standpoint of therapy, the diagnosis may be difficult in many instances. The well-known symptoms and signs are not pathognomonic. Milgram questioned the conception that these tuberculous lesions have an insidious onset. He found that out of 142 verified cases of osseous tuberculosis, the onset was sudden in 29.5 per cent., with severe pain in 26.7 per cent.; and that in 37 per cent. the results of roentgenographic examination were either of no help or were misleading. Much confusion arises from the fact that some of the roentgenographic findings seen in tuberculosis, such as synovitis, periarticular swelling, and bone atrophy, are often found in non-tuberculous arthritides. Osteosclerosis and osteophytic growth are more common in tuberculous lesions than is realized. Diagnostic difficulties may be encountered in tuberculosis of the rib, the sternum, and the sacrum, where the disease is not manifest until extensive destruction has taken place. On the other hand, tuberculous arthritis may be present without destruction of the bone and with entirely negative roentgenographic findings.

Such laboratory studies as the tuberculin test, the hemogram, and the sedimentation test are of limited diagnostic value. According to Seddon, biopsy of the inguinal lymph nodes in tuberculosis of the knee joint is worth while in that a positive result gives confirmatory evidence of the disease. Conclusive proof of the tuberculous nature of an arthritis may be gained by culture or by guinea-pig inoculation of the material obtained by aspiration of the joint, by punch biopsy, or by histological and bacteriological examinations at the time of operation.

During the past seven years the authors have studied twenty-two cases of tuberculosis of the bone, in which an attempt was made to corroborate the clinical diagnosis by bacteriological examination of the fasting gastric contents. Securing gastric specimens for

this purpose is a simple procedure that can be done by the physician, by a trained attendant, or by a laboratory technician. It is preferable to aspirate the gastric contents rather than to wash out the stomach. Aspirations are done on five successive mornings, as soon after rising as feasible, so as to avoid the possible spontaneous evacuation of the stomach contents. In Poulsen and Andersen's investigation of 199 tuberculous children, tubercle bacilli were recovered from the gastric contents in 77 per cent. on the first examination, in 96 per cent. after the second examination, and in 100 per cent. when five stomach washings were done. Our findings are in harmony with these observations.

The fasting gastric contents are aspirated by means of a sterilized, Size 16 French nasal catheter. Smaller tubes are used in children and in infants. The tube is passed through the nose more readily, if it is stiffened by keeping it in a refrigerator before use, and if its tip is moistened with sterile glycerine. It can be easily manoeuvered through the nasal cavity, even in the presence of minor submucous bony deformities or of septal deviations. As soon as the tip reaches the pharynx, the patient is instructed to swallow repeatedly while the tube is passed down the oesophagus. There is very little discomfort from this procedure, and the patients readily accept repeated gastric aspirations. By means of a ten-cubic centimeter or twenty-cubic centimeter glass syringe, the gastric contents are removed and are collected in a sterile container. According to the practice of Poulsen and Andersen, the individual specimens are pooled and used for bacteriological examinations. The authors have found that a greater number of positive results are obtained by using pooled specimens than by examining the same number of specimens individually.

An equal volume of 5 per cent. potassium hydroxide is added to the specimen, and the mixture is placed in an oven at a temperature of 45 degrees centigrade for one hour. It is then centrifuged at high speed for thirty minutes, the supernatant fluid is decanted, the sediment is neutralized with 5 per cent. hydrochloric acid, and washed with saline solution. The sediment is then ready for simple smear, culture, or guinea-pig inoculation. For culture, the material is divided among three slants of Petragnani's medium in oval test tubes measuring 155 by 27 by 17 millimeters. The culture tubes are allowed to remain in an almost horizontal position until the moisture has been absorbed by the surface of the culture medium (usually about forty-eight hours). The tubes are then sealed with a mixture of two parts of paraffin to one part of vaseline, and incubated in an upright position until evidence of bacterial growth is noted, or for a maximum period of eight weeks. The cultures are examined grossly every week. Positive findings may be noticeable in three weeks.

The authors believe that the tubercle bacilli can be detected in the fasting gastric contents as competently and reliably by culture as by animal inoculation. The culture method is, of course, simpler and less expensive. On very rare occasions, one may find non-pathogenic acid-fast bacilli in the gastric contents. These can be identified by their morphological and cultural characteristics, and, in case of doubt, by guinea-pig inoculation.

The presence of tubercle bacilli in the fasting gastric contents carries important diagnostic implications. Their ingestion with contaminated milk can be excluded with reasonable certainty, because the patient is not permitted to take nourishment during the night and morning preceding the gastric aspirations. Furthermore, it is unlikely to find viable tubercle bacilli in the milk from tuberculin-negative herds (tuberculosis in cattle has been virtually eradicated throughout the United States), or in milk which has been pasteurized.

The question might arise as to the likelihood of finding tubercle bacilli in healthy individuals who have been exposed to tuberculosis incidentally or professionally (physicians, nurses, and hospital and sanatorium attendants). It has been the authors' experience, and this coincides with the observations of others, that tubercle bacilli are never

TABLE I

PATIENTS WITH TUBERCULOSIS OF THE BONES AND JOINTS WHOSE GASTRIC CONTENTS CONTAIN TUBERCLE BACILLI

Patient	Age in Years	Race	Sex	Diagnosis	Extent of Bone Lesion Shown by Roentgenogram	Pulmonary Findings Shown by Roentgenogram	Classification on Discharge
M.A.	13	White	F	Tuberculosis of right hip joint	Considerable destruction of head of femur and acetabulum	Solitary calcified nodule in right hilum, and small nodular calcifications in left hilum	Healed
R.B.	6	White	F	Tuberculosis of both hip joints	Extensive destruction of head of femur and acetabulum, bilaterally	Increased hilar densities on both sides. Pleural thickening on left side	Healed
B J.	1½	White	F	Tuberculosis of right hip joint	Destruction of anterior and lateral aspects of femur, extending into epiphysis	Dense bilateral hilar calcifications	Still under observation; improving
M.B.	4	White	F	Pott's disease	Tenth and eleventh thoracic vertebrae, with kyphosis	Few small hilar calcifications	Apparently healed
W.B.	3	Negro	M	Pott's disease	Second and third lumbar vertebrae, with organized psoas abscess	Healed primary tuberculous complex	Healed
L.G.	8	White	M	Pott's disease	Fifth, sixth, seventh, and eighth thoracic vertebrae	Large calcified areas in hilum, bilaterally	Healed
E.K.	8	White	M	Pott's disease	Ninth, tenth, and eleventh thoracic vertebrae, with marked kyphosis	Few calcified nodules in both hilar areas	Improved

found in the fasting gastric juice of healthy persons, or of those with non-tuberculous pulmonary diseases.

Clinically manifest tuberculosis of the tonsils as a source of tubercle bacilli in the aspirated stomach contents is extremely rare, even in patients with long-standing, far-advanced pulmonary tuberculosis. According to Newhart, Cohen, and VanWinkle, a series of 30,676 tonsillectomies showed tuberculosis of the tonsils in 2 per cent. This apparently high figure may not be so startling, if one recalls the incidence of reinfection type of pulmonary tuberculosis found in mass photofluorographic surveys. Roentgenographic evidence of reinfection type of pulmonary tuberculosis existed in from 0.3 to 2 per cent. of the individuals examined. The former figure was recorded in college students. In some of the underprivileged groups, such as recipients of relief and homeless males, the corresponding figures were 4.1 and 16 per cent., respectively. There is no record in the literature of the presence of tubercle bacilli in the gastric contents in persons with latent or subclinical tonsillar tuberculosis, without gross evidence of tuberculous changes in some of the other structures. In the absence of such changes, therefore, the tonsils may be disregarded as a possible source of infection.

The role of tuberculosis of the stomach as a source of tubercle bacilli is insignificant. In a series of 10,000 postmortem examinations, Collinson and Stewart found only three cases of gastric tuberculosis (0.03 per cent.); Gentile reports a collective review of Mirolli, covering postmortem findings in 71,871 cases, which revealed an incidence of 0.21 per cent.; and Sullivan, Francona, and Kirshbaum recorded only two cases of tuberculosis of the stomach in 11,480 postmortem examinations (0.01 per cent.).

Possible sources of tubercle bacilli in the fasting gastric contents are as follows:

1. Frank pulmonary parenchymal infiltration, reinfection type or primary type

which is readily demonstrable by physical examination or roentgenogram, should be considered. If a specimen of sputum is not available, aspiration of the fasting gastric contents and their bacteriological examination are strongly advocated in the presence of such lesions, even if at first glance the lesions may appear well fibrosed.

2. Tuberculous hilar lymph nodes, which always signify a previous or coexistent primary lesion in the lung parenchyma, may discharge tubercle bacilli into the adjacent bronchi. Incontrovertible experimental evidence was presented by Ulmar and Ornstein that tubercle bacilli, in the absence of cough, are carried from the bronchial tract to the pharynx by the ciliary action of the bronchial mucosa and by the normal bronchial peristaltoid motion. From the pharynx, through swallowing, the bacilli reach the stomach. In rare instances, tuberculous mediastinal lymph nodes may discharge tubercle bacilli directly into the oesophagus.

3. Active tuberculous lesions of the lung parenchyma, or tuberculous lymph nodes which are not visualized on a standard postero-anterior roentgenogram of the chest, may be the sources of tubercle bacilli found in the stomach. The difficulty in visualizing these lesions is due to the fact that they are localized in areas obscured by the heart shadow, the mediastinal structures, or by the dome of the diaphragm.

The group of patients presented here belong to the third category. During the past seven years, twenty-two patients with osseous tuberculosis, in whom an attempt was made to confirm the orthopaedic diagnosis by searching for tubercle bacilli in the fasting gastric contents, were treated at the Muirdale Sanatorium. In none of these patients was active pulmonary tuberculosis demonstrated by roentgenogram. The gastric contents were negative in fifteen patients, who had a total of eighty-one gastric aspirations. Seven patients, whose gastric specimens were positive for tubercle bacilli, had forty-six gastric aspirations. There were four cases of Pott's disease and three cases of tuberculosis of the hip joint in the positive group.

Concerning the finding of tubercle bacilli in the stomach contents of patients with orthopaedic forms of tuberculosis, the following points deserve consideration.

1. What is its diagnostic significance? It is the consensus of clinicians that this finding indicates an active tuberculous focus in the body,—usually a tuberculous lesion in the lung parenchyma or in its collateral lymph nodes. In the presence of an orthopaedic involvement of obscure origin, the presence of tubercle bacilli in the fasting gastric contents, though not absolute proof of the tuberculous nature of the disease, should be looked upon as important presumptive or circumstantial evidence.

2. If the assumption is correct that tubercle bacilli in the stomach indicate active tuberculosis, no patient with tuberculosis of the bones or joints should be pronounced cured until repeated bacteriological examinations of the gastric contents are negative for tubercle bacilli. So long as these cultures remain positive, there is a potential danger of spread of the micro-organisms to other parts of the lung, to the bone lesion being treated, or to other hitherto uninvolved structures or organs of the body. It is reasonable to believe that the same tuberculous focus which is discharging tubercle bacilli into the bronchial tree is discharging micro-organisms into the blood stream. The authors believe that healing this source of infection before releasing the patient from treatment would constitute the safest way of avoiding a breakdown of an apparently well-healed bone lesion and of preventing tuberculous complications, such as pulmonary spread or meningitis, which might prove fatal. The frequent incidence of such complications shows the need for a revision of the general management of these cases.

3. Tubercle bacilli passing from the respiratory tract to the stomach are necessarily found in the pharynx during one phase of their passage. Coughing, sneezing, laughing, and crying may expel them into the air, directly exposing all who are in close contact. Coughing may be brought about not only by the tuberculous lesion in the lung or in the lymph nodes, but also by intercurrent non-tuberculous diseases, such as the so-called

common cold, upper respiratory infections, simple or allergic bronchitis, influenza, bronchopneumonia, measles, whooping cough, and a number of others. Although the spread of tubercle bacilli from these patients to those in their environment is not so massive as in the case of an open, advanced pulmonary tuberculosis, nevertheless the risk of infection exists. Undoubtedly, these patients are tuberculosis carriers, and therefore the entire regimen of their management should be revised accordingly.

CONCLUSIONS

1. From the standpoint of optimum therapeutic results and of the prevention of possible local or general complications, the importance of the early diagnosis of tuberculosis of the bones and joints cannot be overemphasized.

2. Because of the inherent limitations of the available physical and roentgenographic methods of examination, the diagnosis of orthopaedic forms of tuberculosis is difficult to establish.

3. Similar limitations are encountered in many cases of pulmonary tuberculosis, the demonstrable evidence of which would give a clue to the diagnosis of an obscure bone or joint disease. Not all active tuberculous lesions of the lung are visible on the standard postero-anterior chest roentgenogram. Small lesions, which may be discharging numerous tubercle bacilli into the blood circulation, may remain obscured by the heart shadow, the mediastinal structures, or the diaphragm.

4. For the sake of accurate diagnosis, it is imperative to resort to methods which are of value in uncovering these hidden sources of tubercle bacilli. Roentgenograms of the chest taken at various angles, such as oblique and lateral exposures, or special apical detail film, are of assistance, but roentgenographic shadows in the lung fields do not identify the etiology of the lesion.

5. The available data in the literature, as well as the authors' experience with over 2,000 cases of pulmonary tuberculosis, indicate that examination of the fasting gastric contents for tubercle bacilli is an indispensable diagnostic procedure. The same method is applicable to orthopaedic forms of tuberculosis.

6. Examination of the fasting gastric contents should be carried out periodically, at intervals of from three to six months, to ascertain the course of the original tuberculous focus in the lung.

7. The conception of complete healing of a tuberculous lesion of a bone or joint should be expanded. No patient should be classified as cured until repeated bacteriological examinations of the gastric contents reveal no tubercle bacilli. Although this may prolong the treatment, there cannot be any doubt that this added regimen is of value in consolidating the healing of the orthopaedic lesion, as well as that of the original source of the disease.

8. Securing gastric contents for bacteriological examination is a simple procedure which can be carried out by the physician or by a trained attendant, with very slight discomfort to the patient.

9. The detection of tubercle bacilli in the fasting gastric contents is as competent and reliable by culture as by animal inoculation.

10. A higher number of positive results are obtainable when five consecutive gastric specimens are examined than where fewer samples are studied. A greater number of positive results may be expected from examination of pooled specimens than from separate examinations.

11. In a group of patients with various forms of orthopaedic tuberculosis, an attempt was made to corroborate the diagnosis by the bacteriological examination of the fasting gastric contents. Out of this group of twenty-two patients, tubercle bacilli were found in seven (31.8 per cent.).

12. With improved laboratory technique and with more frequent examinations of this type, a higher percentage of positive findings may be expected.

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FRACTURE OF THE MEDIAL EPICONDYLE WITH DISPLACEMENT INTO THE ELBOW JOINT *

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A great deal has been written in the last quarter century about displacement of the medial epicondyle into the elbow joint, and a gradual development in the diagnosis and treatment of this unusual condition can be traced in the literature. The first descriptions of manipulative reduction of the incarcerated medial epicondyle were made independently by Fèvre and Roudaitïs (1933) and by Roberts (1934). A comprehensive paper on the whole subject (based on forty-one collected cases) was read by Clarke at the meeting of the Manchester Surgical Society in 1939. Unfortunately, his paper has not yet been published.

Fracture of the medial epicondyle with incarceration in the elbow joint occurs mainly between the ages of ten and seventeen, and is often associated with a traction injury to the ulnar nerve. The condition may occur in either of two ways.

1. As a result of a fall on the hand, the forearm is abducted on the humerus and the strain on the medial collateral ligament avulses the epicondyle. The epicondyle is pulled down to the level of the elbow joint, into which it is sucked by the momentary vacuum which forms in the joint.

2. A posterolateral dislocation of the elbow is associated with a fracture of the medial epicondyle. The epicondyle, being still attached to the medial ligament of the elbow, is displaced along with the radius and ulna. When the dislocation is reduced, the epicondylar fragment lags behind the forearm bones as they pass into position over the articular surface of the lower end of the humerus. Thus only a pseudoreduction is accomplished, in which the epicondyle remains between the coronoid process and the humerus, and a subluxation remains. The epicondyle lies in the joint, with its raw bony surface in contact with the articular cartilage of the coronoid.

This second type of incarceration, following reduction of a dislocation, is the more important, for it is in such cases that the diagnosis is most often missed. In all cases a subluxation is present, although it is only of secondary importance, for, if the incarcerated fragment is replaced early, the subluxation automatically disappears.

Clinical diagnosis is relatively easy, if paralysis of the ulnar nerve is detected. If a good anteroposterior roentgenogram is obtained, there can be no doubt about the position of the epicondyle, but owing to pain and muscle spasm the roentgenologist will frequently be unable to extend the elbow sufficiently for this purpose.

Reduction can often be effected by manipulation, either by abduction of the forearm on the humerus, accompanied by supination and extension of the wrist and fingers to tense the flexor muscles and so pull the epicondyle out of the joint; or by adduction of the forearm on the humerus, associated with flexion and extension movements of the elbow, with the object of expressing the epicondyle, as an orange pip may be expelled by compressing it between the finger and thumb. Clarke has referred to several cases in which spontaneous extrusion has occurred.

When manipulation fails, open operation is necessary, and it is generally recommended that at this time the ulnar nerve should be transposed anteriorly. Various references are made in the literature to the danger of a late ulnar neuritis developing from friction of the ulnar nerve on the rough epicondylar groove in those cases in which anterior transposition has not been carried out.

When incarceration of the epicondyle remains unrecognized for several weeks, open operation becomes very difficult, and even when the epicondyle has been excised, or the

* Read at the meeting of The British Orthopaedic Association, London, June 1, 1945.

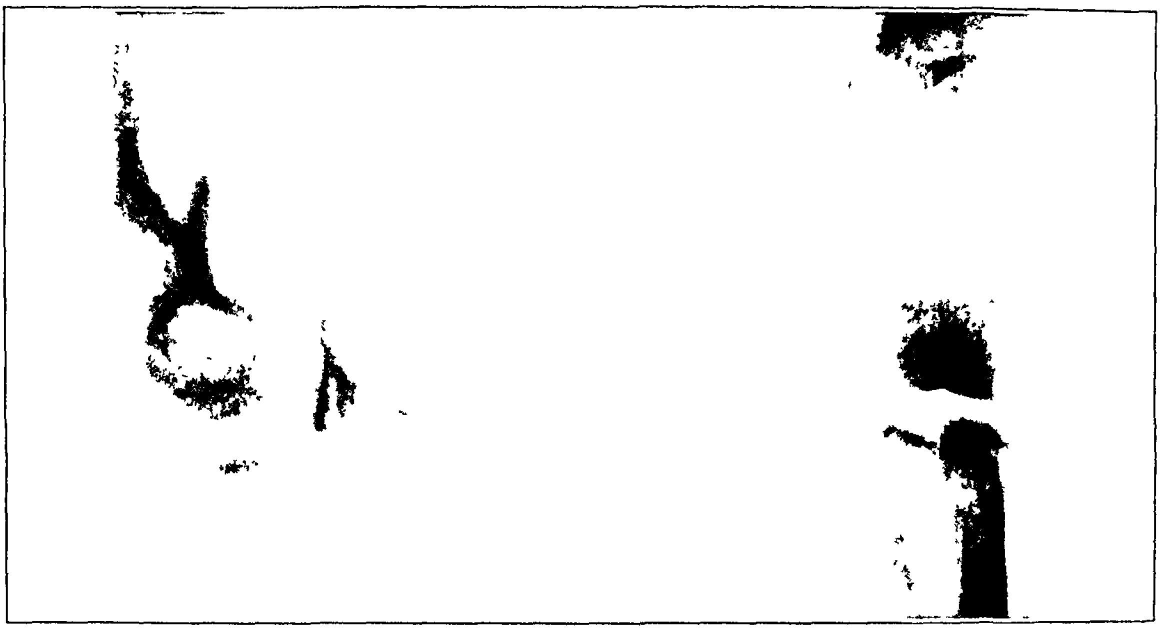

FIG. 1-A
The incarcerated medial epicondyle is seen at the joint level in the lateral roentgenogram.

FIG. 1-B
This anteroposterior roentgenogram could be obtained only by extending the elbow under anaesthesia.

fracture has been reduced, the subluxation almost defies reduction. The final results in late cases treated by operation appear to be uniformly poor; such patients are usually left with a very limited range of movement.

The following observations are based on a series of twenty-one cases treated by the author during the last five years.

The *first problem* which presented itself in investigating this subject was how to make an early and definite diagnosis. Forty per cent. of the patients had no paralysis of the ulnar nerve; therefore clinical diagnosis was not always easy and reliance had to be placed on the roentgenogram. The presence of pain and muscle spasm often prevents the patient from extending his elbow beyond a right angle. As a result, the anteroposterior roentgeno-

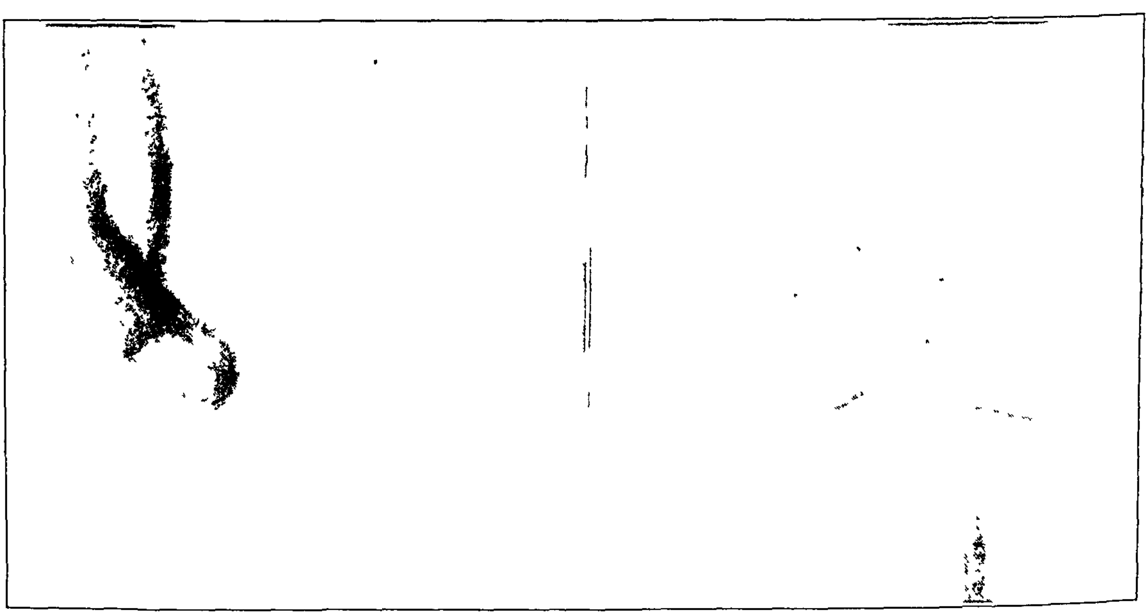

FIG. 2-A
The medial epicondyle can no longer be seen in this lateral roentgenogram. (Compare with Fig. 1-A, taken before reduction.)

FIG. 2-B
The medial epicondyle, now released from the joint, lies above the level of the joint line.

gram needed for accurate diagnosis cannot be obtained, and a lateral view must suffice. If, however, the epicondyle can be seen at the joint level in the lateral view, it may be considered to be in the joint. On reviewing our last 100 cases of simple medial epicondyle fracture, in no instance could the medial epicondyle be seen at the joint level in the lateral roentgenogram. In simple medial epicondyle fracture, the fragment apparently is never pulled down as far as the joint level. Figure 1-A shows the typical appearance, in the lateral view, of a fragment incarcerated in the joint. Diagnosis was based on this view alone, and was confirmed only after the patient had been anaesthetized and a good anteroposterior view had been obtained (Fig. 1-B).

The *second problem* was how to effect an easy and safe reposition of the fragment. In the patients seen by the author, only 40 per cent. of the early fractures were reduced by manipulation, although Clarke and Roberts claim a much higher percentage of success. The standard methods of manipulative reduction, however, may cause a further traction injury to the ulnar nerve. In two of our patients, who initially had no paralysis of the ulnar nerve, a complete nerve lesion appeared after manipulation had been attempted, and lasted for several months. Clarke also refers to patients showing a more profound degree of paralysis of the ulnar nerve, following manipulative reduction.

Reduction of the incarcerated medial epicondyle was carried out in the last six cases in the following manner: The patient was anaesthetized, the forearm gently abducted on the humerus, and faradism applied to the flexor muscles with the wrist held in extension. In all cases the displacement of the medial epicondyle was thus easily reduced, and subsequent treatment was carried out as for a simple epicondyle fracture. The six patients in whom reduction was achieved by faradism were, of course, all early cases. In only one instance had the duration of the injury been five days; in this case, a strong continuous faradic contraction was required, and an audible click was heard as the epicondyle left its lodgment against the coronoid. Figure 2-B shows the roentgenogram after reduction by faradism. The subluxation has simultaneously disappeared. The medial epicondyle is no longer visible at the joint level in the lateral roentgenogram.

Fig 3

This patient had a fracture of the medial epicondyle, displaced into the elbow joint, and inadvertently left unreduced. This photograph shows motion possible five years after injury.

Should faradism not be available, manipulation is more likely to be successful under very light anaesthesia than under deep anaesthesia.

The *third problem* was how to treat a patient whose injury had been unrecognized for five weeks or more. As already stated, the usual method is to operate, extract the fragment, and by the exercise of extreme force and possibly division of the remaining joint ligaments, reduce the subluxation. Such treatment usually results in extreme and permanent limitation of elbow movements. There is one suggestive point which can regularly be observed in the pathological changes in these cases. At operation, the raw bony surface of the epicondyle is found to be firmly adherent to the coronoid process; when the epicondyle has been removed, erosion of the articular cartilage on the coronoid is evident. The muscle and periosteum-covered parts of the medial epicondyle in contact with the trochlea, however, produce no such reaction. No adhesions form between these two apposing surfaces, and erosion of the trochlear cartilage does not take place.

This pathological observation suggests that better results might be obtained in late cases by leaving the epicondyle incarcerated in the joint. Mechanically, the presence of

the epicondyle in the medial compartment of the joint renders the subluxation stable (see Figure 1-B). If the epicondyle is removed from the joint by operation, and the subluxation cannot be reduced (as is sometimes the case), a rather unstable joint results.

This line of conservative treatment was inadvertently carried out in a lad who sustained his initial injury in 1940. He was not seen again until 1945. By that time the medial epicondyle had become fused to the coronoid process, and Figure 3 shows how excellent were the patient's elbow movements. He still had a partial paralysis of the ulnar nerve, which, incidentally, was due to constriction of the nerve by a fibrous band. At operation on the nerve, the interior of the joint and the epicondylar fragment were seen to be covered by a smooth layer of what appeared to be fibrous tissue. The articular cartilage of the trochlea showed no erosion, and no intra-articular adhesions were present.

A bony fusion of the fragment to the coronoid, however, does not always occur. In another case of unreduced fracture, seen eighteen years after the injury, there was only a fibrous union to the coronoid, but, although marked osteo-arthritic masses of bone had formed at the sides of the joint, function was even better than that shown in Figure 3.

The *fourth problem* was how to deal with the associated paralysis of the ulnar nerve. The nerve is damaged by traction, and it would seem that it should recover at least as readily in its normal bed as in a new course made for it in front of the elbow. The one argument against leaving the ulnar nerve alone is that friction with the rough edge of the bone in the epicondylar groove may result in permanent changes in the nerve or, even if recovery occurs, may give rise to a late ulnar neuritis. When such patients are operated upon, however, no sharp bony edge is apparent in the epicondylar groove, the base of the groove being covered with smooth fibrous tissue. Furthermore, if the possibility of such damage existed, one would expect to find a delayed lesion of the ulnar nerve in at least a proportion of the numerous cases of simple fracture of the epicondyle observed in children or in adolescents. The author has never encountered a late ulnar neuritis following such an injury, and Seddon, in the Peripheral Nerve Unit at Oxford, could find among his records no case of late ulnar neuritis following an uncomplicated fracture of the medial epicondyle in adolescents. It seems, therefore, that fracture of the medial epicondyle by itself rarely, if ever, gives rise to ulnar neuritis. Late ulnar neuritis may occasionally follow such an injury associated with dislocation of the elbow, but in this instance it appears to be the soft-tissue damage and the ensuing scarring which cause the neuritis, rather than friction in the epicondylar groove.

In the author's cases of incarceration of the medial epicondyle associated with a lesion of the ulnar nerve, the nerve was left alone and, in all but one instance, recovery occurred within a year. In the one exception (Fig. 3), the persisting nerve lesion was found at operation to be due to constriction by a fibrous band one-half inch above the level of the medial epicondyle.

When the medial epicondyle remains permanently in the joint, a late ulnar neuritis may result, due to subsequent osteo-arthritis and the persistent cubitus valgus deformity, and an anterior transposition of the ulnar nerve may be necessary.

SUMMARY

1. In cases of fracture of the medial epicondyle with displacement into the elbow joint, diagnosis often rests mainly on the roentgenogram. A satisfactory anteroposterior view may be difficult to obtain, but if, in the lateral roentgenogram alone, the epicondyle can be seen at the joint level, it may be regarded as being in the joint.

2. Reduction in early cases can easily be accomplished by anaesthetizing the patient, gently abducting the forearm on the humerus, and applying faradism to the flexor muscles.

3. Cases unrecognized for more than a few weeks are probably best left alone and not subjected to operative reduction.

4. Immediate anterior transposition of the ulnar nerve is unnecessary.

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CONTRACTURE OF THE SCALENUS ANTERIOR, CAUSING ANEURYSMAL VARIX OF RIGHT INTERNAL JUGULAR VEIN

A Case Report

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The scalene syndrome is an interesting diagnostic problem. Neurological and vascular disturbances in the upper extremity may be caused by pressure from a contracted scalenus anterior muscle on the underlying brachial plexus cords and subclavian artery.

Possible etiological agents are congenital, associated with cervical rib; traumatic, following apparently minor strain; and neurological, when evidently secondary to cervical nerve-root irritation. Common sequelae are peripheral neuralgia and circulatory deficiency in the upper extremity.

H. A., a white female, thirty-eight years of age, was first seen on May 7, 1945, and gave a history of pain in the right shoulder of insidious onset ten months before, progressively becoming more severe. There was no definite history of trauma. Treatment elsewhere for bursitis of the shoulder by physiotherapy and anaesthetic injection had given no relief. The woman had been forced to give up her occupation as a beauty-shop operator; she became very apprehensive about her condition, and developed an apparently unrelated axillary dermatitis which was identified by a dermatologist as seborrheic in type. There were no objective neurological or circulatory signs in the extremity. There was palpable tightness of the scalenus anterior, with radiated pain in the shoulder and arm when pressure was sustained. Roentgenograms revealed a normal cervical spine.

Surgical exploration was performed on June 5, 1945, and, after retraction of the lateral margin of the sternocleidomastoid, a sac containing fluid expanded into the incision. This proved to be a saccular dilatation of the internal jugular vein, about three centimeters in diameter. The vein was ligated above and below the sac, which was excised, exposing the right lymphatic duct and the scalenus anterior. The muscle was definitely tight and somewhat thickened; so it was sectioned above its insertion. After closure the wound healed well, there was complete relief of symptoms, and no evidence of vascular insufficiency. Microscopic section added nothing to the gross diagnosis of aneurysmal varix.

This case presents apparent interference with the venous flow in the right internal jugular vein by compression of the scalenus anterior, causing an aneurysmal dilatation of the vein in the base of the neck. The right internal jugular vein is the larger and normally deviates farther laterally than its associate, the carotid, at the base of the neck. Apparently in this instance the junction with the subclavian vein to form the innominate was more lateral than usual, allowing the pressure from the scalenus anterior.

SURVIVAL OF THE HEAD OF THE RADIUS IN A CHILD AFTER REMOVAL AND REPLACEMENT

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From the Department of Surgery of the Washington University School of Medicine, St. Louis

In a paper published some years ago it was emphasized that the head of the radius should not be removed in children, as its removal would interfere with the growth of the forearm.[1] The writer had not previously seen a head of the radius which was completely detached and which then was replaced and survived, nor has he observed a report of any such case.

On March 11, 1944, a boy, eleven years old, was brought into the Hospital on account of a fracture of the proximal end of the radius. According to the history, the elbow had been dislocated, and the dislocation had been reduced on the previous day. However, the head of the radius was displaced in the posterior portion of the joint. The patient was operated upon the following day, approximately forty-eight hours after his original injury.

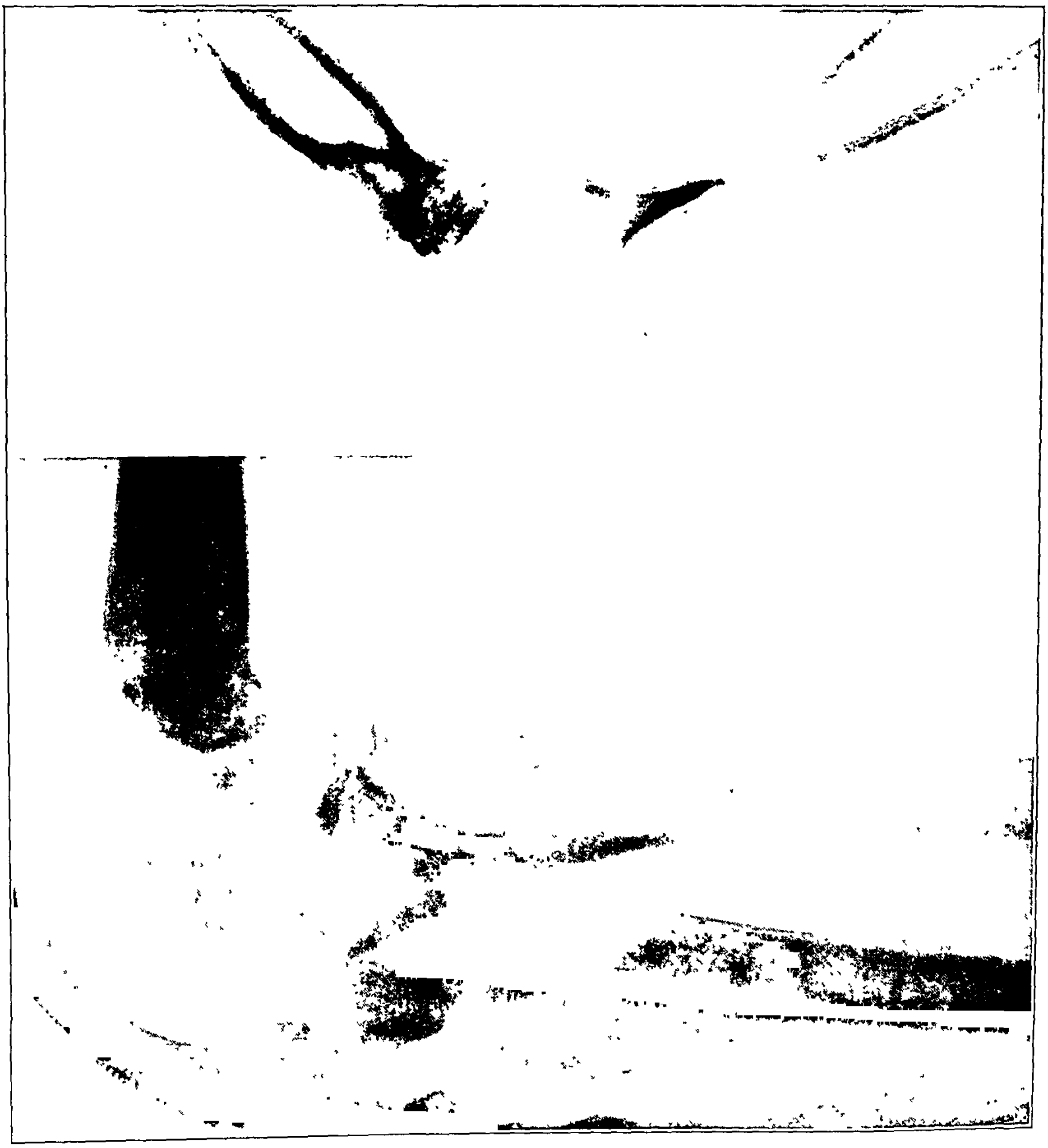

Fig. 1

Dislocation of the head of the radius. Preoperative and postoperative views.

FIG. 2

Anteroposterior and lateral views of the same elbow about thirteen months later. Function is approximately normal.

The elbow joint was opened by a posterolateral incision, extending from the epicondyle of the humerus downward along the anterior border of the anconeus. The head of the radius was found in the posterior portion of the joint behind the external condyle (Fig. 1). It was completely free, and was lifted out with toothed forceps and placed in a towel on the instrument table. The stump of the neck of the radius was then exposed, and the head was replaced in approximately its normal position. The elbow was flexed to 90 degrees, and the soft tissues were sutured around the head. The fragment of the head included the epiphyseal line. The wound was closed, and the elbow was immobilized in a posterior plaster mold. The patient left the Hospital a few days later, and the convalescence was uneventful. Immobilization was continued for eight weeks, at the end of which time the cast was removed, and the patient was advised to use the arm with care.

He returned for a check-up examination a little over thirteen months after the operation. Movement of the elbow was almost normal, there being approximately 5 degrees' less extension than on the normal side. There was no pain; the arm seemed strong; and there was satisfactory growth of bone, although the late roentgenograms (Fig. 2) showed an irregularity of the epiphyseal plate.

This case is reported because it is a clinical example, supporting the statement that epiphyses should not be removed in children. If the epiphyses are found to be displaced, they should be replaced, because they may survive, even though they are completely without blood supply.

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SEVERE PELVIC FRACTURES TREATED BY FIXED SKELETAL TRACTION

Report of a Case

BY MAJOR J. D. FARRINGTON

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Pelvic fractures are usually treated satisfactorily either in a canvas sling with continuous traction, as described by Key and Conwell, or by plaster fixation after reduction. The reduction may be accomplished by lateral recumbency, according to the method of Watson-Jones.

Occasionally one is confronted with multiple fractures, in which the entire half of the pelvis has been displaced medially. Some method of forceful lateral traction must be applied to reverse the compressive force which produced this type of injury. The problem is similar to that encountered in central dislocation of the head of the femur. Continuous lateral traction has produced good results in reducing the fracture, but requires long recumbency, constant surveillance, and a great deal of nursing care.

Immediate reduction and immobilization of fractures in plaster-of-Paris is the ideal treatment when such factors as transportation over long distances, or the strain on hospital and nursing facilities in overseas hospitals, must be considered. When continuous traction is employed, pulmonary complications, decubitus ulcers, and phlebothrombosis are constant threats, unless individual nursing care is instituted.

CASE REPORT

A white soldier, aged twenty-three years, was injured on February 1, 1944, when he fell from a control tower at a base in the South Pacific area. The soldier was descending a vertical wooden ladder, wet with rain, and slipped at a measured height of fifty-two feet, falling free to strike a packed coral surface. The full impact of the fall was concentrated against the right trochanter. On admission to the hospital, thirty minutes after the injury, the patient was in a state of moderate shock, and complained of severe pain throughout his pelvis and lower back. This was increased by any movement of his lower extremities. Roentgenograms (Fig. 1) revealed multiple fractures of the pelvis with anterior rotation and medial displacement of the main fragment, consisting of the greater part of the ilium, the acetabulum, and the ischium. The iliac fracture was parallel to the sacro-iliac joint. There was boardlike rigidity of the entire abdomen, with exquisite tenderness over the bladder. Approximately 250 cubic centimeters of bloody urine were obtained by catheterization. The surgical consultant explored the bladder, repaired a tear at its base, and inserted a large suprapubic de Pezzer catheter. A urethral catheter was also inserted. The general condition of the patient prevented any immediate definitive treatment of the fractures. He was put to bed, and skin traction was applied to the widely abducted right lower extremity. Three transfusions of whole blood, each of 500 cubic centimeters, were given during the first six days. Pain was severe and constant, and nursing care was a problem.

After consideration of the roentgenograms, fixed lateral skeletal traction and immediate plaster immobilization were decided upon. To this end, the apparatus pictured in Figure 2 was set up. The skeletal reduction frame was placed transversely on the operating table, with the portable fracture table placed over it on a narrow wooden platform, just high enough to allow the entire reduction frame to be moved freely in any direction.

Fourteen days after the injury, when the patient's general condition had improved a good deal, he was given a general anaesthetic, and a femoral twin-pin unit was inserted into each trochanter. The patient was then placed on the fracture-table saddle, and the twin-pin units were fixed in the fracture frame. Satisfactory reduction was obtained by traction on the right femoral twin-pin unit, aided by manual pressure against the right iliac crest. With this method, the traction was against the fixed left side of the pelvis, and, after reduction, the right side could be locked in place. A double hip spica cast was applied from the costal margins to the toes, because it was believed that the patient would be more comfortable with the hamstring muscles immobilized.

The change in the general condition of the patient was gratifying. Whereas, prior to immobilization, frequent doses of morphine were necessary to control pain, none were required after the application of the cast. The patient was turned every two or three hours with no discomfort, and nursing requirements were reduced to a minimum.

The patient was scheduled for evacuation one week after application of the cast, but this had to be

FIG. 1
Roentgenogram of pelvis after patient had fallen fifty-two feet.

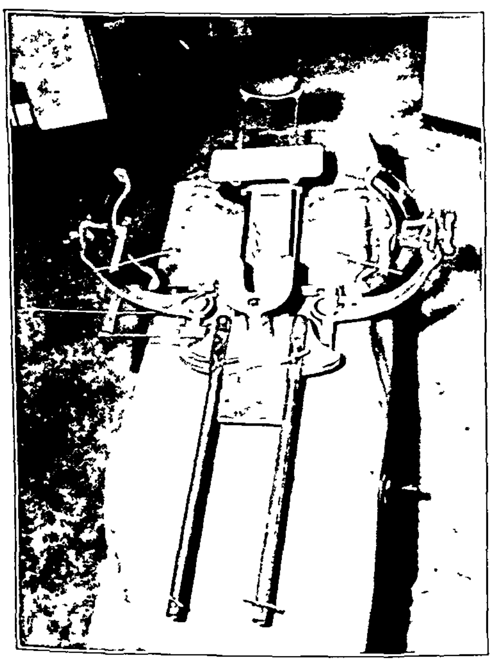

FIG. 2

FIG. 3

FIG. 2 Combination apparatus set up for reduction of fractures. Arcs of the reduction frame are turned longitudinally. Entire reduction frame may be moved in any direction, beneath the support for the fracture table, to facilitate engagement of the femoral units.

FIG. 3: Surgical technician demonstrating position of patient in the apparatus.

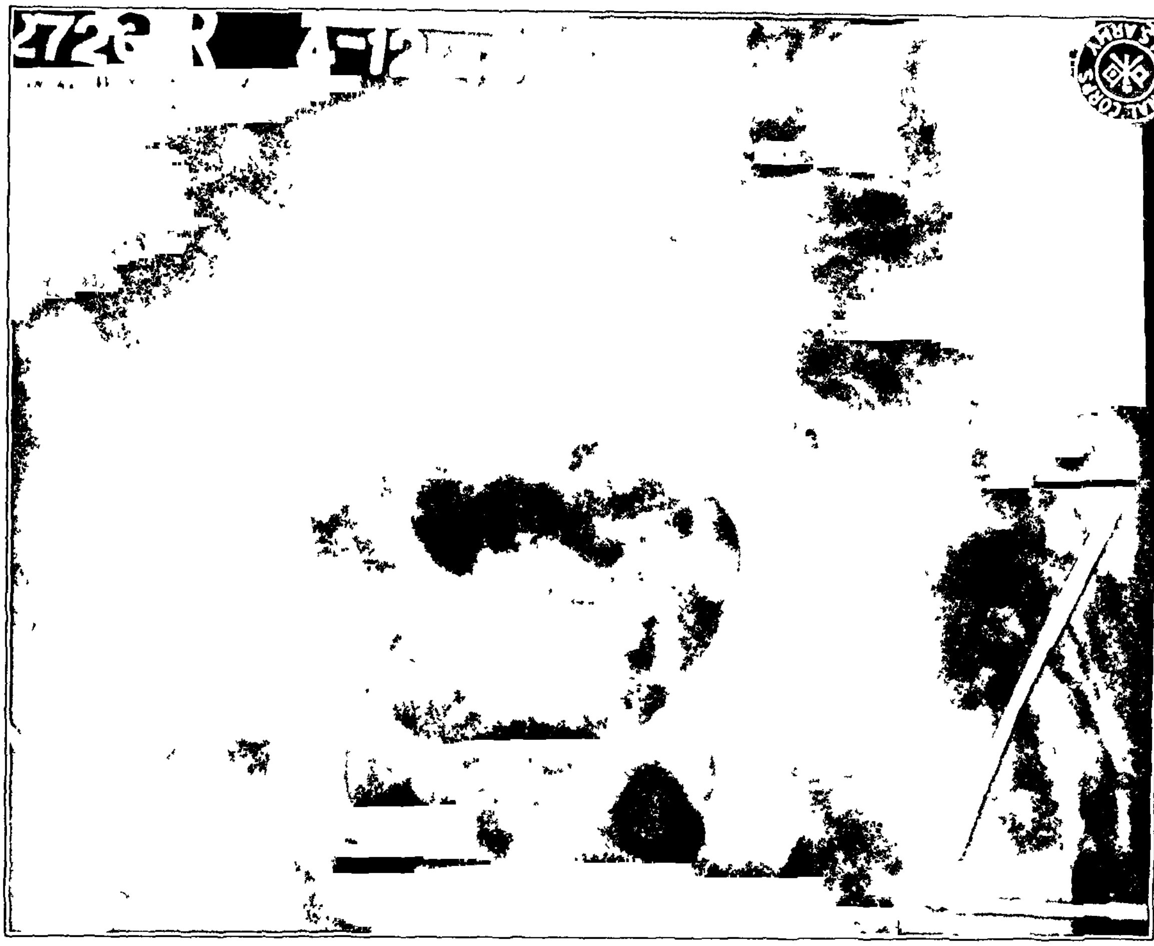

FIG. 4

Roentgenogram of pelvis fifty-seven days after reduction of multiple fractures. Pelvic ring and contour of right ilium restored.

postponed, because of the development of acute pyelitis with high temperature. This complication cleared up with adequate therapy, and did not recur.

On March 14, 1944, four weeks after reduction of the fracture, the patient began to complain of pain when turned, due to looseness of the cast from loss of weight. He was again placed on the fracture table with the twin-pin units locked in the reduction frame to maintain position; the old cast was removed, and a double hip spica cast to the knees was applied. A basal anaesthesia, consisting of one-quarter grain of morphine and 1/150 grain of scopolamine, was adequate for this procedure.

On March 26, the patient was evacuated in plaster; at that time he was comfortable, afebrile, and was voiding urine spontaneously. The suprapubic wound had healed. Roentgenograms (Fig. 4), taken on April 12, 1944, while the patient was still in the second cast, revealed that reduction had been maintained. At the time of last correspondence, the patient was out of plaster, but not yet ambulatory.

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TRICHINOSIS AS A CAUSE OF MERALGIA PARAESTHETICA

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From the Beth David Hospital, New York

Meralgia paraesthetica was first described by Bernhardt in 1895. The clinical syndrome is one of paraesthesia, pains, and some objective sensory loss over the anterolateral aspect of the thigh, which is believed to be the result of a hyperplastic reaction of the nerve sheath of the external femoral cutaneous nerve. The sensory disturbances consist of various forms of paraesthesia of the outer side of the thigh, sometimes with diminished sensation or hypaesthesia. The symptoms may persist for years and produce a good deal of discomfort, exaggerated by walking or by the touch of clothing. The disease has been considered a neuritis, which originates in the nerve when it passes under the inguinal ligament, deep and just medial to the anterior superior iliac spine. The condition is said to occur more frequently in men; in 1900 Musser and Sailer collected ninety-nine cases, of which seventy-five were in men. A large number of cases are attributable to single or repeated trauma to the nerve, such as pressure from a belt or corset over the anterior superior spine. Pregnancy and obesity are mentioned among the causes, as well as static disturbances, such as weak feet.

The peculiar anatomical location of the lateral femoral cutaneous nerve in its passage over or under the sartorius muscle, as well as its proximity to the anterior superior iliac spine, renders it extremely susceptible to compression from any lesion of the sartorius or its fascia. Thus in the majority of cases, an abnormally placed fibrous band may be responsible for the pressure neuritis. The case to be reported disclosed such a fibrous band, which on microscopic study proved to be caused by trichinosis. Further investigation not only revealed the probable time of invasion of the trichinae, but also gave a positive intradermal test. Although a survey of the literature revealed myositis to be a constant finding in trichinosis, its possible relationship to meralgia paraesthetica has not heretofore been mentioned. Clinically, the muscles most affected by the migration of the larvae through the blood stream are the gastrocnemius, deltoid, biceps, and those around the eye; less often the muscles of the diaphragm, abdominal wall, and thorax are affected; rarely, but of greater seriousness, the intercostals, muscles of mastication, deglutition, and speech, and occasionally the cardiac musculature, are involved.[2]

CASE REPORT

D. N., a male, aged forty-two, was first seen by the author on October 13, 1944; the patient complained of coldness and numbness of the anterolateral aspect of the right thigh of four years' duration. The complaints were preceded by "pins and needles" and by hot and cold sensations over a small circular area of the distal and outer portion of the thigh. The paraesthesia would last for about half an hour, subside, and then recur at variable intervals. At first the symptoms were most noticeable at night and interfered with sleep, but they were soon followed by paraesthesia during the day. Walking increased the severity of the pain and the number of attacks. After one year of the paraesthesia, the patient first noted numbness of the greater part of the outer thigh. The numbness was present chiefly on arising in the morning; by night the patient was tormented with sensations of pins and needles and hot and cold flushes over the anterolateral aspect of the thigh. The numbness soon became steady by day, and was the chief complaint when the patient was first seen by the author. In addition to the large area of numbness, there was a smaller area of "burning", located several inches below the anterior superior spine, so that even the rubbing of clothes against the skin became painful.

The past history was interesting in that five years before, after eating pork, the patient had become quite ill, with fever and diarrhoea.

The physical examination revealed a well-developed muscular male, who appeared to be in excellent general health. Examination of the right thigh revealed normal musculature and muscle tone. There was no restriction of motion in the hip, knee, or ankle. The peripheral circulation was unimpaired. The abdominal examination was entirely negative. Gross neurological examination revealed marked hypaesthesia to pinprick over the anterolateral aspect of the thigh, corresponding to the dis-

tribution of the external cutaneous nerve. Pressure over this nerve, immediately below the anterior superior iliac spine, resulted in pain, radiating down the course of the nerve. Ankle jerks and knee reflexes were unimpaired, and no abnormal reflexes could be obtained.

Roentgenographic examination of the pelvis and right femur failed to disclose an osseous lesion.

On December 2, 1914, with novocaine infiltration anaesthesia, the superficial and deep fascia of the thigh were exposed through a six-inch hockey-stick incision, extending for three inches along the anterior crest of the ilium to the anterior superior spine, and then distally for an additional three inches. Incision of the deep fascia disclosed the interval between the sartorius and tensor fasciae latae, revealing the lateral femoral cutaneous nerve. This was traced proximally to the anterior superior iliac spine, where it was found rather deeply placed in the osseous hollow immediately below the spine. Here the nerve was markedly encroached upon by a thick fibrous band. The band was in intimate contact with, and appeared to be part of, the inferior surface of the sartorius. A probe, which was passed proximally along the nerve, was stopped by the dense constriction. The fibrous band was carefully excised, revealing a thinned segment of the nerve. At this point the patient exclaimed that the numbness of the thigh had disappeared. A probe could now be passed easily beneath the inguinal ligament. Closure was performed, using plain catgut for the subcutaneous tissue and silk for the skin. An alcohol dressing was applied, and was overlaid with several gauze bandages for pressure.

At biopsy, the gross specimen consisted of a small fragment of striated muscle and intervening fibrous tissue, measuring 1.5 centimeters in length and 0.5 centimeter in width.

Microscopically, the section revealed muscle fibers, which were partly fragmented and showed signs of degeneration and fibrosis. Part of the muscle was entirely replaced by fibrous tissue. There was increased fat tissue between the muscle fibers. Numerous cysts of *Trichinella spiralis* were scattered throughout the section. None of the cysts were calcified, and there was no cellular infiltration around the cysts.

Laboratory findings after the operation revealed a positive skin test for trichinosis, and a negative precipitin test. The complete blood count showed a hemoglobin of 97 per cent.; red blood cell count 4,930,000; white blood cell count 13,600; color index 0.99; total polymorphonuclear neutrophils 66 per cent., of which 59 per cent. were segmented and 7 per cent. were non-segmented; eosinophils 4 per cent.; basophils 1 per cent.; lymphocytes 25 per cent.; and monocytes 4 per cent. There were no abnormal blood cells.

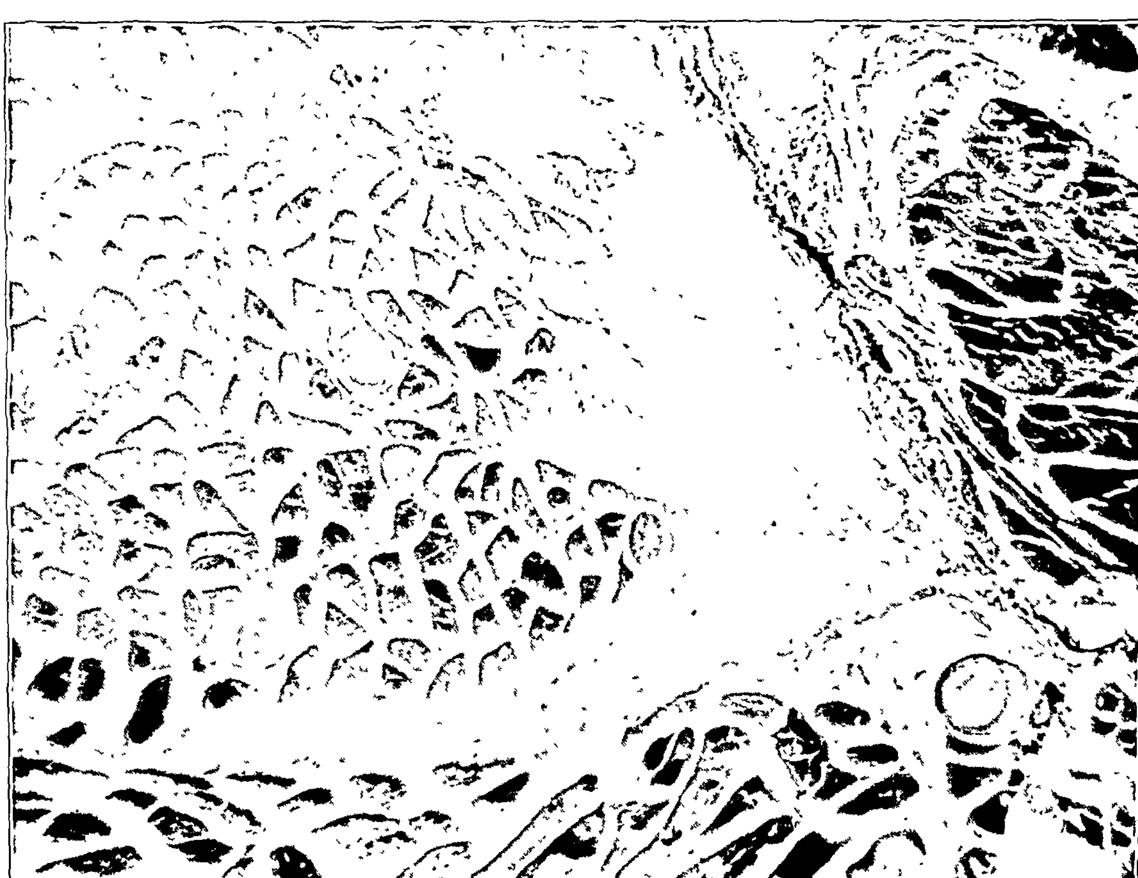

Fig. 1

Low-power view of fibrous band, showing mulitple cysts of *Trichinella spiralis*.

Fig 2
High-power view of cyst of *Trichinella spiralis*.

Fig 3
High-power view, showing muscle degeneration and fibro-fatty replacement of muscle. Note absence of round-cell infiltration.

The diagnosis was chronic fibrous myositis and trichinosis.

The postoperative course was complicated by the development of a hematoma, which delayed healing for several weeks. The patient was last seen four months after operation, and stated that the numbness of the thigh had almost completely subsided, and that there had been a return of normal temperature sensations to the thigh. Objectively, the hypaesthesia to pinprick had completely disappeared, with the exception of a small patch, the size of a fifty-cent piece, immediately below the anterior superior spine.

NOTE: The author wishes to express his appreciation to Dr. Gudeman, of the Department of Pathology, for assistance in the interpretation of the pathological material.

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LOCALIZED COCCIDIOIDOMYCOSIS OF BONE

Report of a Case

BY CAPTAIN M. L. GOREN
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Coccidioidomycosis, or infection caused by the *Coccidioides immitis,* was first described by Rixford and Gilchrist in 1896. The fungus producing this infection is diphasic. In the *saprophytic* phase, it consists of septate hyphae, which appear white and cottony on solid media, and become pigmented with age. The infective portion of the fungus presumably occurs in nature in the form of chlamydospores. In the *parasitic* phase in animals, the fungus is made up of sporangia, or spherules.[1] In the living organism the chlamydospores round up into spherules, and cleavage planes divide the protoplasm into segments, which develop into endospores within the double refractile wall. Mature spherules may vary from ten to sixty microns in diameter, or may even be as large as 200 microns in diameter. The endospores may be arranged radially, or grouped in the center. The spherule wall ruptures, and releases the endospores to spread in the animal and grow into mature spherules. Spread in the animal is by way of the blood stream or the lymphatics. In nature, the fungus is limited to certain arid regions. Its host is unknown, although Emmons suggests a rodent reservoir.

The problem of coccidioidomycosis has been emphasized in the present war, due to the training of a large number of troops in the arid Southwest, where *Coccidioides immitis* is endemic. The disease has protean manifestations, and has both immediate and latent effects on the infected host.

Smith [7] divides the disease into the following categories:

1. Initial or primary infection:
   (a) Inapparent or asymptomatic form;
   (b) Acute respiratory, "influenzal", or "pneumonic" form;
   (c) Either of above types associated with erythema nodosum, or multiforme (known as "San Joaquin fever", "Valley fever", "desert fever" or "desert rheumatism");
   (d) Pulmonary cavity form.
2. Progressive, "secondary", disseminated infection (usually fatal, known as coccidioidal granuloma, chronic granulomatous coccidioidomycosis, "San Joaquin Valley disease", or "California disease").

Smith further states that the respiratory tract is the only significant portal of entry, but that: "Occasional infections have been credited to abrasions". Perhaps one infection in 500 or 1,000 develops into the disseminated form. When this does occur, the results are disastrous. Every attempt should be made to localize the disease by rest, until clinical and laboratory findings show that the infection is being well controlled.

In coccidioidomycosis, giant cells and caseation occur, not unlike those seen in tuberculosis; it can be distinguished from tuberculosis only by the finding of the double-contoured spherules. Carter states [3] that bony lesions are usually multiple, involve cancellous bone, and are frequently associated with considerable new-bone formation, as well as with destruction of bone. An individual lesion is rarely distinguishable from that of tuberculosis.[4]

REPORT OF A CASE

A twenty-two-year-old negro soldier was admitted to Torney General Hospital on May 12, 1944, for treatment of an infection of the index finger, which had persisted for five months. The patient cut his left index finger on January 1, 1944 on a jagged tin can, while doing kitchen police as a patient at a numbered General Hospital, during desert training, near Indio, California. He was receiving treat-

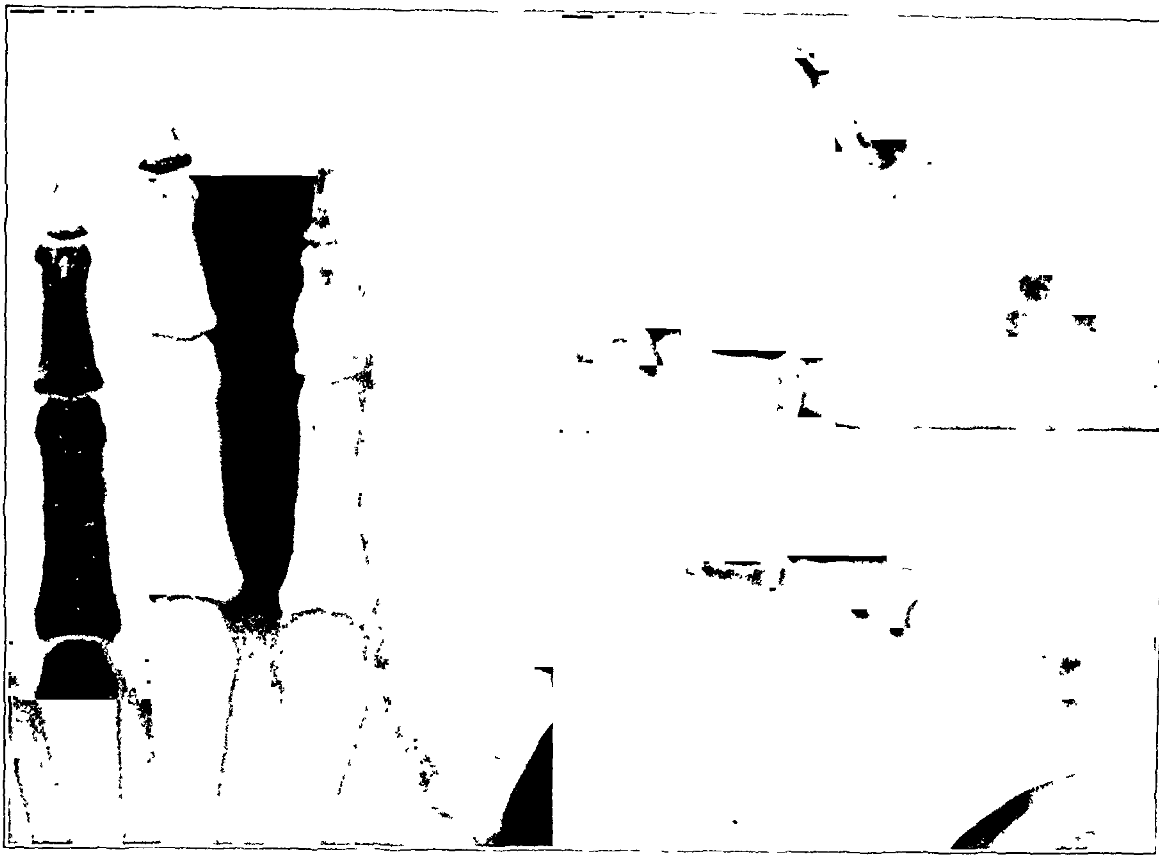

Fig. 1
Roentgenogram of left index finger, taken June 3, 1944. (*U. S. Army Signal Corps.*)

ment for infectious jaundice at that time. The finger became swollen and stiff. The patient was treated with saline soaks for several weeks, and, after the swelling had partially subsided, was discharged to continue his duties as a driver of a weapons carrier. Some swelling and stiffness in the index finger persisted, and about May 1, 1944, the skin on the dorsum of the middle phalanx broke open, and a purulent material was discharged. The patient was then sent to the Hospital.

Examination upon admission to Torney General Hospital revealed a well-developed male negro, who was five feet, ten inches in height, and weighed 155 pounds. The examination by systems was negative for abnormalities, except for the left index finger. This revealed a swollen middle phalanx with brawny induration, and a small two-millimeter sinus on the dorsum, which was discharging a thin, purulent material. The joint movements in this finger were normal and painless. Cultures were taken from the draining sinus, and were reported as hemolytic *Staphylococcus aureus* and *Staphylococcus albus*. Cultures for fungi showed a Microsporon, which was not further identified.

The roentgenographic examination (Fig. 1) revealed a localized destruction of cortex, and invasion of the medulla of the middle phalanx of the left index finger, with very little osseous regeneration. The epiphyseal ends of the bone were free from involvement.

For four weeks sulfonamides were given orally, and hot wet dressings were applied to the finger, without improvement. On June 9, a plastic amputation of the index finger, through the head of the proximal phalanx, was performed under ether, nitrous oxide, and oxygen anaesthesia. The uninvolved volar skin over the middle phalanx was utilized as a long flap to close the end of the amputation stump. The sutures were removed after twelve days, and the wound healed by first intention. The patient was given active physiotherapy for the finger, and was discharged to duty on July 22, 1944, after a program of thorough reconditioning.

Specimen No. 1326 was sent to the Army Medical Museum, Washington, D. C., for examination. The pathological report of Lieutenant Colonel Hans F. Smetana was as follows:

"*Gross Specimen*: The specimen consists of two distal phalanges of the left index finger, measuring 5 by 2 by 1.5 centimeters. The finger is swollen. On the dorsal surface, there is an ulceration measuring one centimeter in diameter, whose edges are indurated. The center shows granulation tissue, and a small amount of yellowish-white purulent material. The nail is intact. The skin of the volar surface of the medial phalanx is missing.

"*Microscopic Specimen, Section A*: This section shows a sinus tract which leads through an ulceration of the surface epithelium into the corium and subcutis. The squamous epithelium at the margin of the fistula is irregularly thickened and its rete pegs extend into the corium. The sinus tract is lined

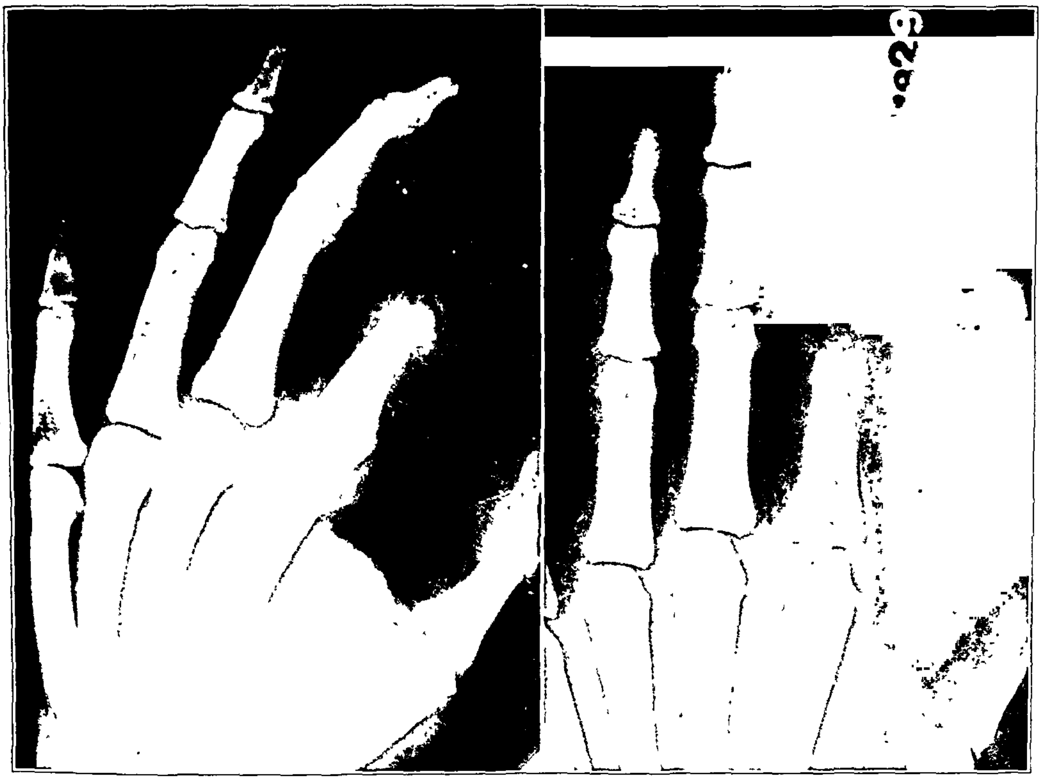

FIG. 2
Amputation stump, two weeks after operation. (*U. S. Army Signal Corps.*)

by a granulation tissue which is infiltrated with lymphocytes, plasma cells, eosinophils, and a few polymorphonuclear leukocytes. In the granulation tissue are seen tubercles, which are composed of epithelioid cells and giant cells of the Langhans type. There is no caseation. Branches of the sinus tract run perpendicular to the main course. One of these branches appears to contain caseous material, and it is lined by numerous small tubercles. In another area, solitary and conglomerate tubercles are scattered through the corium and through papillary bodies. Accumulations of polymorphonuclear leukocytes are encountered in some places. Infiltrations, composed of lymphocytes and plasma cells, have occurred in several situations in the corium, and in the subcutis, and are sometimes quite conspicuous about vessels and skin appendages in the deeper layers of the corium. A medium-sized vein in the wall of the sinus tract shows complete obliteration of its lumen by fibrous tissue of the thickened wall. Within the tubercles are seen very occasional spherical bodies with a double-contour membrane; their shells are sometimes indented. No contents of these bodies can be made out.

"*T. B. Stains*: No acid-fast organisms are seen.

"*Section B*: Except for mild lymphocytic infiltrations in the corium, there are no pathological changes.

"*Section C*: This represents a cross section through the second phalanx of the index finger. The skin surface shows an ulceration leading to a sinus tract, which reaches the periosteum of the middle bony phalanx. The entrance to the sinus tract is lined by squamous epithelium, continuous with that of the epidermis. The tract itself is lined by granulation tissue, and contains fibrinopurulent exudate. In this exudate are seen several spherical bodies, which are surrounded by a colorless hyaline, double-contoured membrane, and contain a bluish granular material, and vacuoles. Within the bone marrow there is a large area which is composed of tubercles, made up of epithelioid cells and Langhans' giant cells. The center of this area shows necrosis, resembling caseation. Within this material, as well as within some of the giant cells, are again seen spherical bodies with a double-contoured refractive membrane containing bluish granular material. The remaining portion of the bone marrow of the phalanx is mainly fibrous in character, and contains but a few islands of hematopoietic cells. There is moderate activity of osteoblasts in some places, and osteoclasts are occasionally seen in lacunae.

"*Section D*: It represents a longitudinal section through the two terminal phalanges. The skin surface is intact. In the subcutis of the dorsal aspect is seen an area of necrosis, surrounded by tubercles and granulation tissue. No spherical bodies are, however, encountered in this region. Within the bone

marrow are several conglomerate tubercles, composed of epithelioid cells and Langhans' giant cells. The central portion shows necrosis. Several spherical bodies with a double-contoured membrane, but without bluish material in the center, are present. The remaining bone marrow is partly fibrous in character and also shows areas of serous atrophy of the fat tissue. Hematopoiesis is minimal, and there is mild activity of the osteoblasts. The joint cavity between the two phalanges appears unchanged.

"*Note*: The non-budding spherical bodies in the exudate are compatible with spherules found in coccidioidal granuloma. The circumstances of the infection, however, are unusual in that it seems to have occurred after injury of the finger due to handling of a tin can. Since there is no other demonstrable localization of coccidioidomycosis, the case is interpreted as primary coccidioidomycosis of the finger, secondary to a superficial cut or abrasion, and progressing to the deeper tissues, and into the bone marrow, with fistula formation."

After the pathological examination disclosed *Coccidioides* in the tissues, a coccidioidin skin test and complement-fixation test were done. These tests were found to be positive.

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BILATERAL SIMULTANEOUS DISLOCATION OF THE SHOULDERS

Report of a Case

BY CAPTAIN THEODORE A. LYNN, *Medical Corps, Army of the United States*
AND COLONEL LEONARD T. PETERSON, *Medical Corps, United States Army*

Simultaneous bilateral dislocation of the shoulder joints is rarely seen. Only seven such cases have been reported since 1930, and information on one other case was gained by personal communication. In 1929, Dreyer reported fifty-seven cases, including one of his own, gleaned from the world's literature from 1846 to 1927. This makes a total of only sixty-five known cases in nearly one hundred years. Most of these patients have had acute dislocations, which were reduced within a short time after the injury. At least nine of the reported cases occurred during some kind of convulsive seizure. The remainder were the result of ordinary traumatic incidents. Coover's case was not recognized early, and reduction could not be accomplished by conservative methods. Open replacement was not considered, because of the patient's age and physical condition. By means of traction and manipulation under anaesthesia, Leadbetter was able to reduce bilateral dislocations which had been present for one month in a muscular negro male, and he obtained a good functional result.

The following patient, who was seen more than two months after his injury occurred, required open reduction and repair of both shoulders to obtain a satisfactory result. The authors know of no other case treated in this manner after such an interval.

CASE REPORT

A navigator of a medium bomber, aged twenty-five, sustained subcoracoid dislocations of both shoulders when his airplane crashed in a remote overseas region on April 18, 1942. He was propelled forward between the seats of the pilot and the copilot, and his shoulders were driven hard against the

Fig. 1

Roentgenogram made eight weeks after injury. Note dense soft-tissue calcification lateral to upper humeral shaft on right.

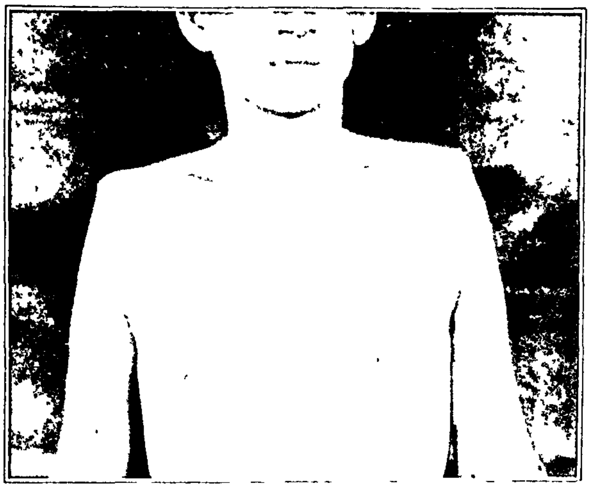

FIG. 2

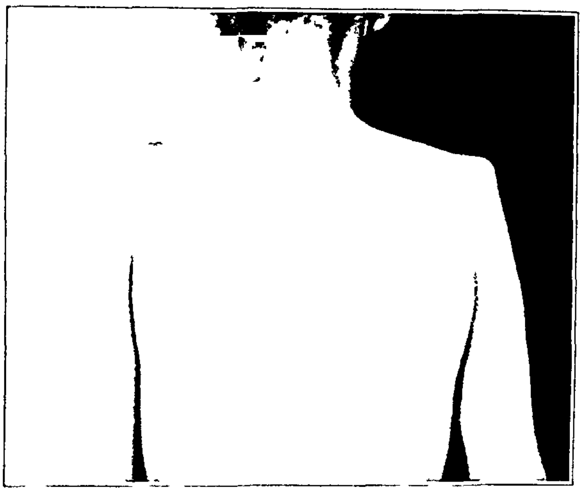

FIG. 3

Photographs eight weeks after injury, showing typical symmetrical deformity of shoulders. No voluntary motion was possible.

seat backs, as the plane struck the water and overturned. No treatment other than first aid was available until June 16, 1942, when the patient arrived in the United States and was admitted to Walter Reed General Hospital. Since the muscles of both shoulder regions had undergone marked atrophy, the diagnosis of bilateral dislocation was readily made on clinical examination. The roentgenograms (Fig. 1) confirmed the presence of subcoracoid dislocation of both shoulders, fracture of the left greater tuberosity, and calcification in the torn shoulder-joint capsule on the right. There was some atrophy of the intrinsic hand muscles innervated by the ulnar nerve on the left, and minimal ulnar hypaesthesia was present. At the time of admission, there was no axillary nerve paralysis, nor other nerve or vascular injury.

In view of the long duration of the dislocations, which resulted in bone atrophy and contraction of soft tissues, reduction by closed manipulation was not attempted. On June 19, open reduction, together

FIG. 4

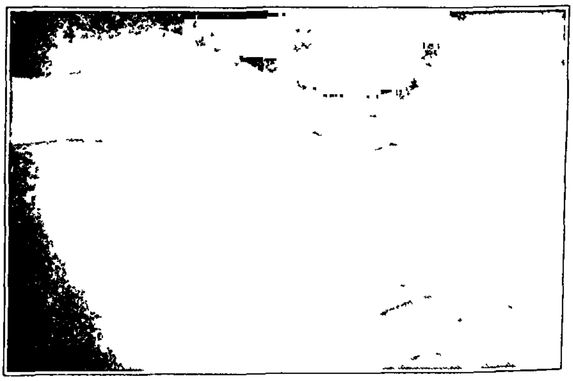

FIG. 5

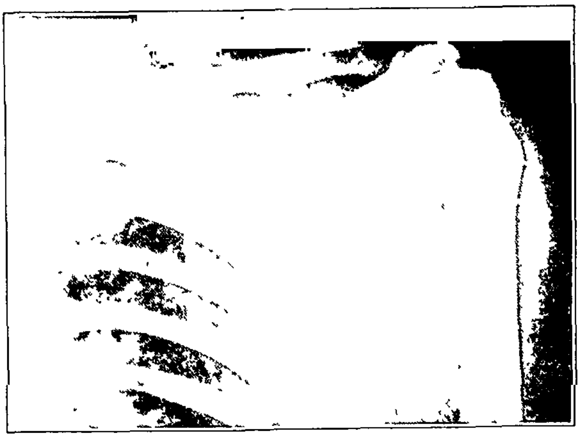

FIG. 6

FIG. 7

Roentgenograms of shoulders at rest, and at limits of abduction, two years and nine months after open reduction and the Nicola operation had been performed.

FIG. 8

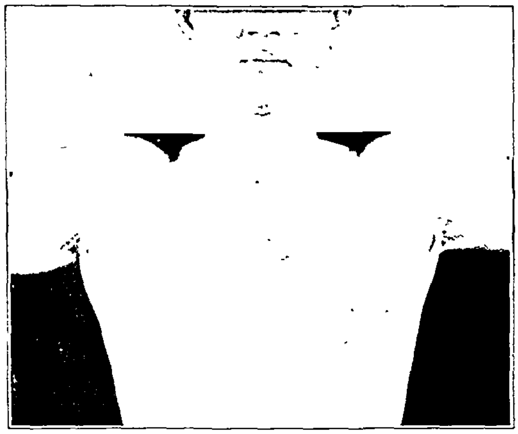

FIG. 9

Photographs two years and nine months after surgical treatment of shoulders, showing range of active abduction. Note excellent development of deltoid muscles.

with repair by the Nicola method, was done on the right shoulder, and on July 7 a similar procedure was done on the left shoulder. The shoulders were immobilized for one month after the second operation, and then active motion was started. By January 1943 the patient had obtained fair motion in both shoulders, but was moderately restricted in rotation and abduction; he had no pain. All evidence of ulnar nerve damage had disappeared. He was discharged to limited duty in February 1943.

The patient was readmitted to the Hospital in February 1945, after he had completed two years of flight duty, as an instructor in aircraft navigation, without serious difficulty. The range of motion was improved. Abduction and flexion up to 90 degrees were possible bilaterally (Figs. 4 to 7). There was moderate restriction of rotation, and some pain in both shoulders on vigorous motion. The patient had exercised faithfully, had excellent muscle power and development (Figs. 8 and 9), and was well satisfied with the results obtained.

It was thought that the left shoulder was the easier to treat from a technical standpoint. This is attributed to the fact that the patient had had traction applied to that shoulder for a period of eighteen days prior to operation, whereas no traction had been applied to the right shoulder. The traction served to promote relaxation of the joint capsule and surrounding structures, and thus facilitated open treatment.

Delayed treatment in this case was not a matter of choice, but occurred because no adequate facilities for treatment were available for the two-month period during which the shoulders remained dislocated. It would be preferable, of course, to accomplish reduction soon after occurrence of the injury.

Prolonged physical therapy in the form of active exercise is essential, if good results are to be obtained following late open reduction of shoulder dislocation.

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AN APPLIANCE FOR THE CONSERVATIVE TREATMENT OF ACROMIOCLAVICULAR DISLOCATION

BY MAJOR MURRAY E. GIBBENS
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Most acromioclavicular separations will heal without deformity or disability, if the dislocation is reduced and is held in place for six weeks. Failures are usually due to interrupted or to inefficient fixation. There have been many methods of treating this condition. The quickest and easiest method of fixation is a Velpeau type of adhesive strapping, with a felt pressure pad over the olecranon process and another over the outer end of the clavicle. Adhesive strapping, however, has its limitations. It stretches, slips, and "gives" after four or five days, and, even though reinforced, becomes loose and uncomfortable. It often irritates the skin, and does not adhere well in hot weather. Taping is an excellent emergency procedure for a few days, but it must be replaced by a more efficient fixation.

The recent literature has contained descriptions of a number of devices, consisting of rather bulky casts, straps, or a combination of the two. Straps alone have a tendency to slip off the shoulder or elbow, and fixation is not constant. A body cast is uncomfortable, hot, and unnecessary.

The light arm "compression-cast", used by the author, has two extension bars, one in front and one in back, and an adjustable rubber elastic strap over the shoulder and the outer end of the clavicle. This has been employed on approximately ten or twelve patients, including one female patient, over a period of several years. (It is impossible to apply adhesive strapping to a woman with well-developed breasts.) The cast is well tolerated by the patients. It is light and comfortable, and permits a small amount of active motion in the shoulder without interruption of fixation. It provides a constant downward pull on the outer end of the clavicle, and an upward pull on the elbow and arm. It is easily constructed by any skillful plaster technician.

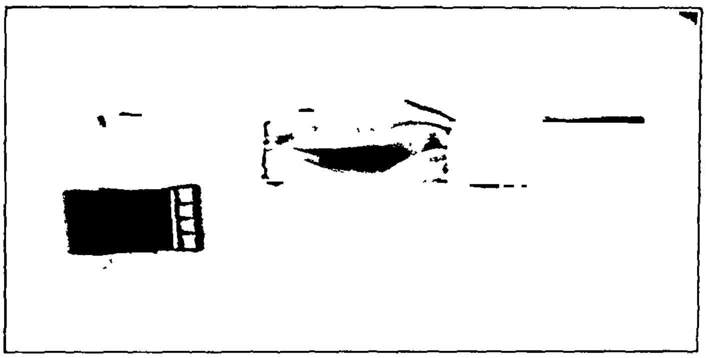

FIG. 1

Shoulder strap, composed of webbing, one and one-half inches wide, and section of rubber glove.

The strap with rubber elastic (Fig. 1) is previously prepared to go over the shoulder. A loop is made in the ends of the strap to fit over the extension bars. The rubber elastic may be a folded section of rubber glove, from which the fingers have been removed, a section of inner tube, or an Esmarch bandage. This elastic material is treated with rubber cement, sewed to the straps, and then wrapped with adhesive tape. A buckle is attached. Several of these elastic straps, with buckles and loops, may be kept in reserve.

Stockinette is used over the arm, and may or may not include the wrist and hand. The wrist is padded with sheet cotton. A felt pad is placed beneath the elbow, and another inside the arm, just below the axilla.

To make the extension bars, two aluminum strips, approximately three-quarters of an inch wide and eight inches long, are prepared and bent into hockey-stick form. About eight wooden tongue depressors are soaked in plaster until pliable. Later, these tongue depressors are bent and are used to reinforce the aluminum strips, being fastened in place with a roll of plaster.

A cast is now applied to the arm, extending as high up under the axilla as possible.

FIG. 2-A FIG. 2-B FIG. 2-C

Views of completed cast.

The ends of the stockinette are turned down over the plaster and sealed with plaster. When the cast is sufficiently strong, and has begun to set, the extension bars are completed and attached with plaster bandage. The elastic strap is attached to the extension bars, and adjusted loosely over the shoulder. A felt pad, four inches square, is used over the outer end of the clavicle beneath the strap to prevent chafing and pressure sores.

Figures 2-A, 2-B, and 2-C show the completed cast. The patient is advised to go to bed and lie on his side until the cast is dry. When dry, the elastic strap is tightened with the buckle. The tightness of the strap and the reduction of the dislocation are checked by palpation with the finger tip, and confirmed by roentgenogram.

The patient is advised to exercise the hand, and is encouraged to move the shoulder through a small range of abduction daily (approximately 5 to 10 degrees). The cast is removed in six weeks, and active motion of the shoulder is started.

This treatment is equally effective for fixation of fractures of the distal end of the clavicle with downward displacement of the outer fragment, preferably after manipulative reduction has been accomplished under anaesthesia.

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MODIFICATION OF CALOT PLASTER JACKET FOR IMMOBILIZATION OF THE CERVICAL SPINE

BY LIEUTENANT COLONEL SAUL RITCHIE
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The author has observed for several years * that the Calot jacket, when applied to correct abnormalities of the cervical spine, does not adequately immobilize the head and neck. Within a week the head and neck usually have range of motion, and the desired position of hyperextension is no longer maintained. There are several other undesirable features: The patient is unable to shave; food and liquids may easily be spilled on that portion of the cast which covers the chin; and proper oral hygiene is impossible. These factors cause irritation of the underlying skin, and discomfort to the patient.

About ten years ago the author modified the Calot jacket so as to leave the lower face and neck completely free. The principal modifications were as follows: The cast was extended across the forehead; two half-inch leather straps were included in the forehead piece; the cast was trimmed differently; and a special chin strap was added to anchor the head firmly.

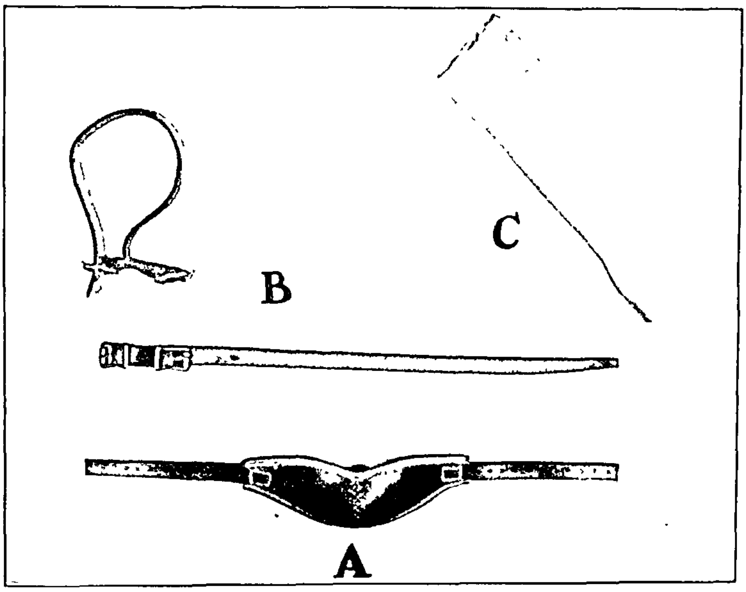

Fig. 1

Supplementary items used in modified Calot jacket.
A: Chin piece.
B: Straps.
C: Felt enclosed in stockinette.
(Photograph by Public Relations Office, Foster General Hospital, Jackson, Mississippi.)

The two leather straps have double buckles, and are eleven inches long and one-half inch wide. The buckles, each one-half inch wide, are placed, one at the end of the strap, and the other one and one-half inches proximal to the end. The strap is doubled back on itself, and the three layers between the two buckles are riveted or sewed together.

The chin strap is similar to the chin piece of a Sayre head traction strap, and may be made of leather or canvas, or of a plastic material lined with leather. A half-inch strap six inches long, with holes punched at half-inch intervals, is sewed to each corner.

The cast is applied with the patient on an Albee or Hawley fracture table. If a fracture table is not available, a piece of board three inches wide, and of sufficient length to reach the seventh cervical vertebra, can be nailed to a wooden table. The hair on the head is clipped closely. The patient's head, neck, and body to a point below the hips are then covered with stockinette, since very little padding is used under the cast. The stockinette covering the body is split at the level of the armpits, and fastened across each shoulder with several strips of adhesive tape. A piece of six-inch stockinette is then pulled over the head and neck, slit to fit the contour of the neck, and fastened with adhesive tape, at shoulder level, to the stockinette covering the body. A hole is cut in the nasal region to facilitate breathing.

Next a piece of soft felt, one-half inch thick, is placed over the region of the occiput, the shoulders, and the crest of each ilium. With the patient supine, an assistant holds the

* In civilian practice.

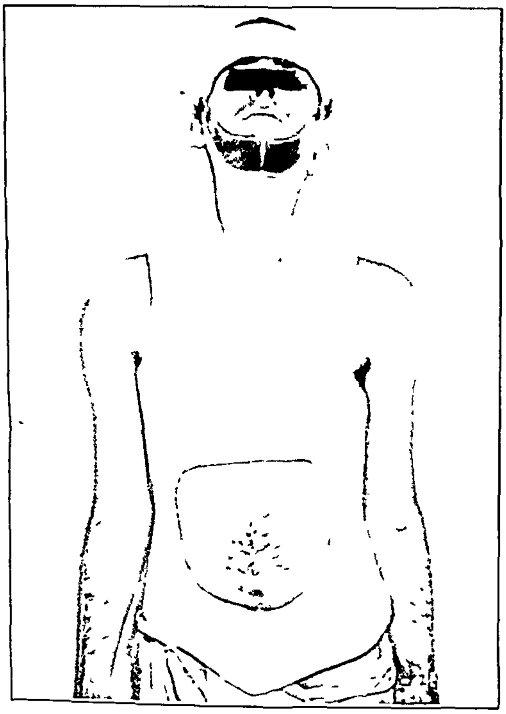

FIG. 2-A

FIG 2-B

Application of modified Calot jacket (Photographs by Public Relations Office, Foster General Hospital, Jackson, Mississippi)

head and neck in hyperextension while applying continual traction by means of a flannel bandage around the chin under the stockinette. A piece of soft felt, one-half inch in thickness, three inches wide, and six inches long, enclosed in three-inch stockinette, is placed across the lower chin and the anterior cervical region.

The Calot cast is then applied in the routine manner, except for the following modifications:

First, a three-inch width of plaster is brought to the level of the eyebrows. After several turns of plaster have been made, the leather straps previously described are placed vertically on each side, just anterior to the ear. The ears are well padded. The end buckle is placed directly below the edge of the plaster covering the forehead, and the straps are left unbuckled. Several additional turns of plaster are applied, so as to cover the straps but not the buckles. The strap is then placed through the second buckle encircling the forehead piece. The strap is now firmly incorporated in the head piece with plaster, leaving only the end buckles exposed.

Second, it is essential that the head piece be firmly attached to the body of the cast with plaster splints, since that is the weak spot. When the plaster has set, the excess plaster over the vertex is removed, and the forehead piece is trimmed so that its lower edge is exactly level with the eyebrows. The portion covering the chin is trimmed sufficiently to allow withdrawal of the piece of felt incorporated in the stockinette. This permits adequate room for swallowing, as well as for the application of the chin strap. The remainder of the plaster over the chin and neck anteriorly can be completely removed after several days, when the cast has set. The plaster over the ears is not trimmed until the following day, to ensure maintenance of cast strength. The body portion of the cast can be trimmed immediately (Figs. 2-A and 2-B). The chin support is now fixed in position by inserting the straps at either end through the buckles in the forehead piece. The straps are pulled tight enough to keep the eyebrows level with the lower edge of the forehead part of the cast. This level is the guide at all times as to whether or not the head is properly fixed.

When the cast has been completed and the patient has returned to bed, a pillow should be placed under his shoulders so that the back of the head does not touch the bed until the cast has thoroughly dried. *If this precaution is not taken, the cast may break* in the region of the neck. The patient may be ambulatory in this type of cast.

This cast has been employed in cases of fracture and fracture-dislocation of the cervical spine, and in cervical osteomyelitis. It does away with the difficulties associated with shaving, feeding, and oral hygiene. During these procedures the chin piece is removed temporarily, the plaster-of-Paris band around the forehead adequately maintaining hyperextension of the cervical spine.

A UNIVERSAL SPLINT FOR DEFORMITIES OF THE HAND

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The introduction of adequate apparatus to correct the deformities caused by nerve injuries was an innovation of World War I. The problems presented by nerve injuries in the present conflict have changed very slightly from those of the preceding War. Earlier diagnosis and exploration, as well as speedier transportation to Special Treatment Centres, may have resulted in few severely contracted, withered extremities. This has decreased the need for drastic corrective apparatus, but has not altered the susceptibility of paralyzed muscles to overstretching. Early application of splints has stressed the necessity for comfortable devices that may be worn for long periods, and yet preserve the function and mobility of the uninjured parts.

There is a fundamental need for apparatus that corrects and controls the classic deformities of individual nerve paralyses. In the past this has been recognized and, as a rule, the splints produced dealt with one deformity and one degree of severity of this deformity. Apparatus that can easily be adjusted and altered to meet individual variations in type and severity will be of value.

The correction of combinations of nerve deformities and injuries to nerve vessels presents a problem which is also best met by adaptable apparatus. Similarly, the frequent association of injury to bone and to soft tissue alters the usual deformities of nerve damage.

Individual variations in skeletal and muscular structure make it desirable that an appliance be especially constructed for each patient. Such a need is obviously difficult to fulfill, and can best be met by using a standard framework, to which adjustable parts are added.

Immediately following injury, and during transport to Special Treatment Centres, the treatment of injuries to bone and soft tissue is paramount, and is best accomplished by plaster. Serious contractures often result, however, when associated nerve deformities are similarly treated. The nerve deformity is better controlled by apparatus that preserves mobility and can be incorporated in the plaster.

When physical and clinical requirements have been met, attention should be given to practical considerations, such as ease of application, inconspicuousness, and weight. The design should be simple enough to permit quantity production.

The cardinal principles of mechanotherapy are to maintain the paralyzed part in relaxation, to avoid immobilization, to prevent overstretching, and to eliminate pressure on areas which are anaesthetic or devitalized. In the hand, the unequal balance of the flexor and extensor muscles is a constant threat of deformity. Extension at the metacarpophalangeal joint is strongly produced by the common extensor and weakly opposed by the interossei and lumbricales. Flexion at the interphalangeal joints is strongly produced by the superficial and deep flexors, and is also weakly opposed by the interossei and lumbricales. The resulting tendency to metacarpophalangeal hyperextension and interphalangeal hyperflexion may best be avoided by maintaining gentle flexion at all three joints.

DESCRIPTION OF SPLINT

To meet the above considerations, a splint has been designed with a universal chassis, or holder, to which accessories may be added that will correct most hand deformities. The splint includes features of the original spring appliance of Henry Meige, and uses an improved spring similar to that suggested by Thomas. The main interchangeable parts

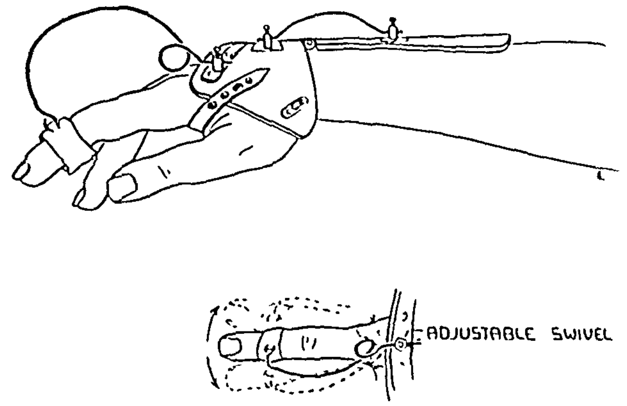

FIG. 1

Universal splint with posterior springs. Note that the leather rings support the fingers proximal to the distal joint.

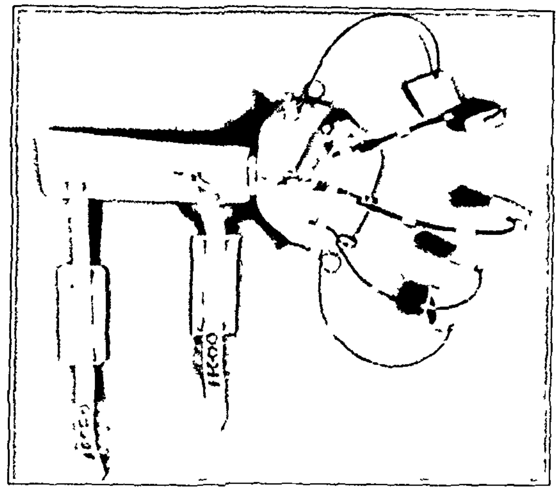

FIG. 2

Shows the posterior springs for fingers and wrist in place. The finger springs are held in studs, allowing lateral movement.

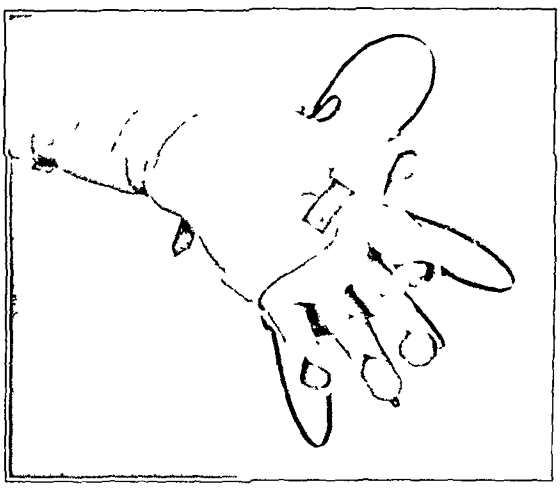

FIG. 3

Palm support may be applied so as to leave the wrist free and allow use of the hand. Note that the individual support of the fingers preserves the normal transverse arch of the palm.

FIG. 4

Correction of medial two fingers in ulnar deformity. Leather rings support the fingers close to the tip to correct the deformity.

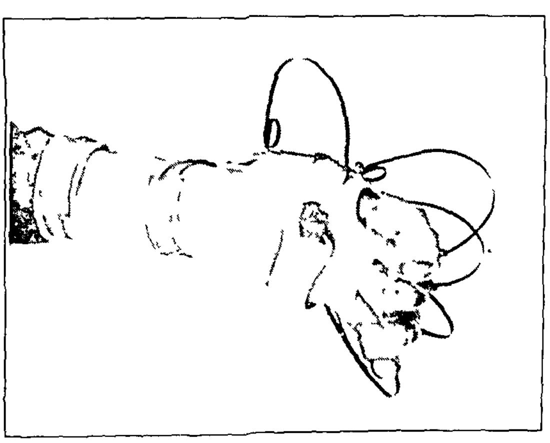

FIG. 5

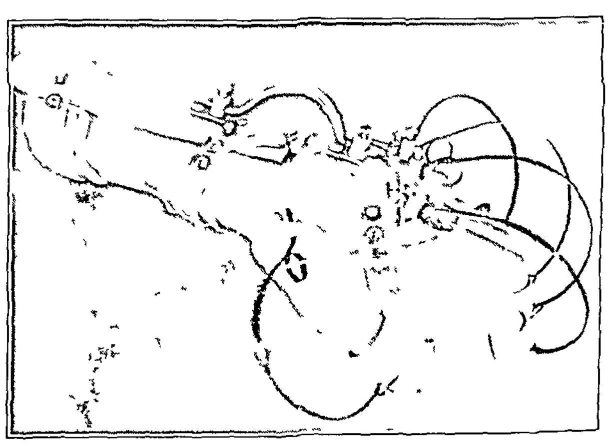

FIG. 6

The splint as applied in a paralysis of the median nerve, requiring finger and thumb correction. Note that the thumb may be pulled from position of adduction.

are steel arches, which are connected to the fingers by leather rings. They are constructed of locksmith's spring steel, 0.125 inch by 0.025 inch in size, and have a single coil at the base of the arch. The direction of the coil spring governs the axis of tension on the finger,—that is, anteriorly or posteriorly. At the same time, the direction of tension may be adjusted accurately for individual fingers by simply bending or straightening the finger arches. The temper of the locksmith's spring steel allows flexibility, and yet it will maintain the correction permanently. The spring arches are held on the chassis by studs on a fixed swivel which can be rotated, adjusting the angle between the fingers.

The chassis is made of aluminum and is easily processed; the palm is supported by a lateral tongue attached to the hand piece, which may be bent to accommodate the size of the hand.

Full wrist movement is permitted by a simple hinge, and the joint is guarded by an adjustable spring which is attached posteriorly. This spring may support the wrist in dorsiflexion, or may be reversed, maintaining volar flexion. The strength may be increased by adding one, two, or three bars, fitted into the same clamps. If no movement is desired, the spring may be locked at any desired angle. All buckle fasteners have been replaced by a simple stud-and-eye connection.

Five combinations have been most commonly used to date. The splint has been designed to be as universally flexible as possible, and there may actually be as many types as there are cases. It is expected that the surgeon in charge of each case will exercise his own ingenuity in adjusting tension, direction, and position.

1. *Posterior Splint*: The basic unit consists of a universal chassis, posterior finger springs, and a posterior wrist spring. It is used chiefly in paralyses of the radial and posterior interossei (Figs. 1, 2, and 3). It may also be adapted to the claw deformities of ulnar and median-nerve lesions. For ulnar lesions, springs are usually necessary for the medial two fingers only (Fig. 4). Slight flexion at the wrist is often necessary to relax associated contractures of the forearm. In lesions of the median nerve which need splint-

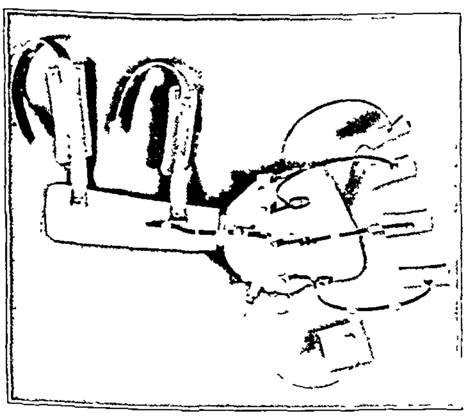

Fig. 7

Universal chassis with hyperextension guard and posterior springs.

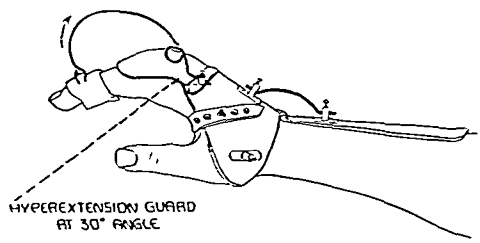

Fig. 8

Lateral diagram, showing application of hyperextension guard.

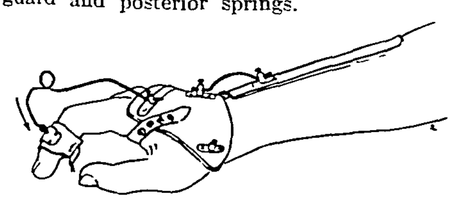

Fig. 9

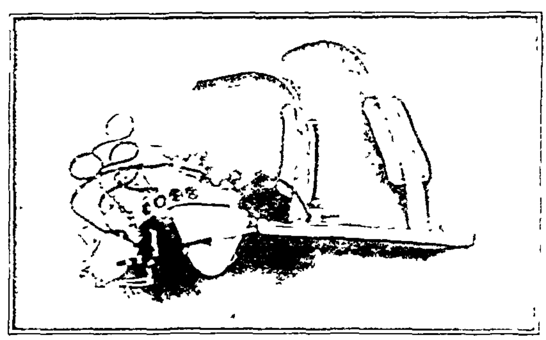

Fig. 10

Anterior springs attached to the universal chassis.

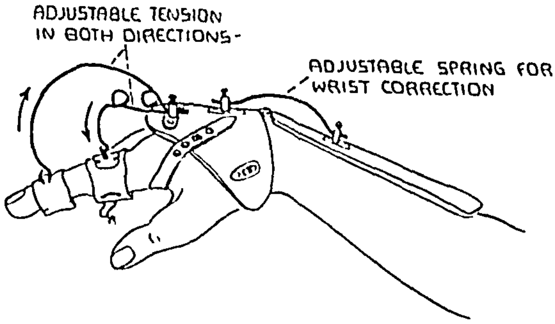

FIG. 11

Fig. 11: Shows scheme of combination springs attached to the chassis.

Fig. 12: Combination splint, as applied to severely contracted hand.

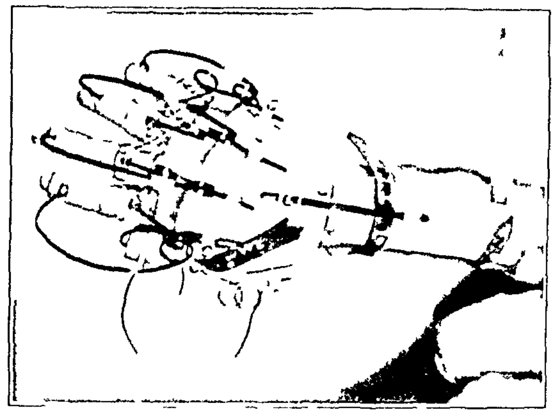

FIG. 12

ing, the claw deformity of the finger may be relaxed by posterior springs, and the thumb may be pulled anteriorly from its persistent adduction (Figs. 5 and 6).

2. *Posterior Splint Plus Hyperextension Guard*: In many cases, the hyperextension at the metacarpophalangeal joint must be continuously corrected to allow relaxation at the interphalangeal joints. This may be done by a fixed guard, maintaining from 20 to 30 degrees of flexion (Fig. 8). The guard may be applied for a while and removed, or it may be applied after it is apparent that adjusting the posterior arch alone is inadequate.

3. *Anterior Splint*: The splint may be converted into an anterior model by attaching springs with the coil exerting pressure anteriorly. Such a splint is most frequently needed for hands severely contracted in extension, often from plaster immobilization. The springs exert pressure through little metal cups attached to adjustable leather thongs (Figs. 9 and 10). The tension needed and the direction of application will vary for each finger, and should be adjusted by the surgeon. The continued pressure exerted by the springs tends to correct deformities fairly rapidly, thus necessitating more supervision to keep the coil spring continuously exerting maximum pressure. Associated wrist deformity may also be corrected by using anterior or posterior wrist springs, as indicated.

4. *Combination Splint*: For those cases with a severe claw deformity, injuries to the nerve vessel, and ischaemia, a combination model is available. The usual deformity of hyperextension at the metacarpophalangeal joint and hyperflexion at the distal joints is corrected by short anterior springs and long posterior springs, properly adjusted as to strength and length (Figs. 11, 12, and 13). The wrist correction may be done concomitantly. In applying this model, the fingers are put through the short springs first and then through the long holders, as in putting on a glove. Any tendency to wrinkling of the skin over the proximal interphalangeal joint may be corrected by adjusting the size of the leather holders. The tension exerted by the coil springs will need to be adjusted as the deformity is gradually corrected.

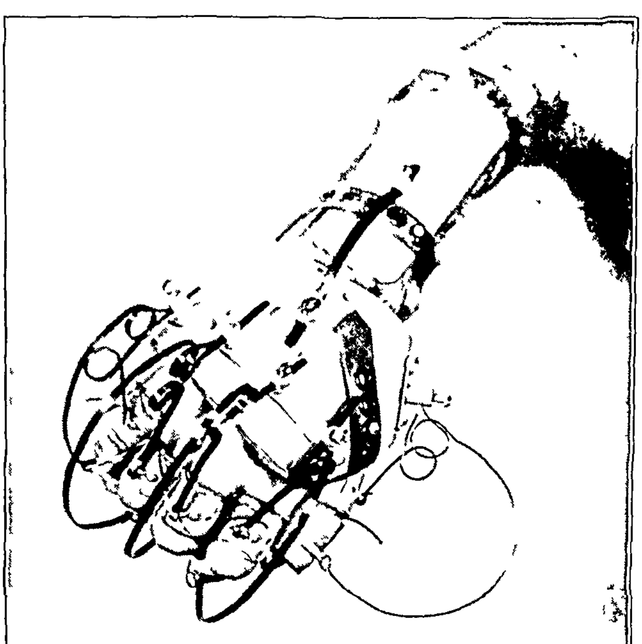

FIG. 13

Demonstrates range of movement still possible.

5. *Plaster Accessory*: Plaster immobilization of many nerve injuries has been

Fig. 14

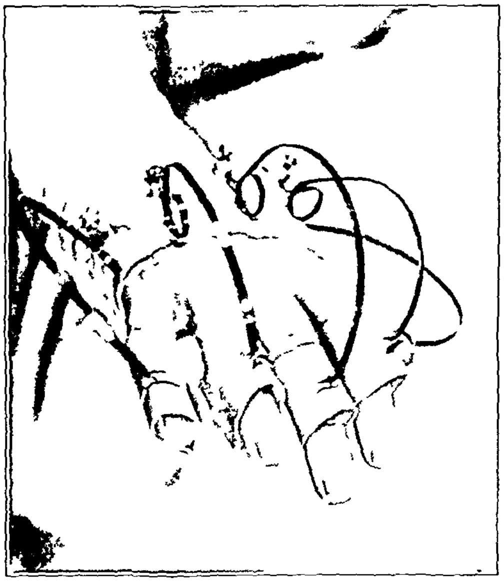

Fig 15

Fig 14: Accessory stud holder in place in plaster cast

Fig. 15: Posterior springs applied, supporting fingers in slight flexion in fractured shaft of humerus with paralysis of the radial nerve

used as a method of splinting, frequently leading to severely contractured, almost irreparable injuries of the extremities. To enable adequate relaxation and to retain mobility, a plaster accessory is used (Figs. 14 and 15). It consists of the stud holder of the universal chassis, which may be attached and incorporated in any cast. Suitable springs may then be inserted in the usual manner.

As in the use of all corrective apparatus, there are certain precautions to be taken.

1. To be certain that the springs exert the proper tension, the splint should be adjusted by the surgeon in all cases.

2. Hyperextension at the metacarpophalangeal joint must be guarded against, particularly in weak hands. This may always be prevented by properly adjusting the spring arch or by using the hyperextension guard.

3. In all cases, the fingers and wrist should be put through a full range of movement at least twice daily.

RESULTS AND CONCLUSIONS

Approximately 400 patients with deformities resulting from injuries to nerves, nerve vessels, and associated soft tissues have been treated by various models of this splint. The splint has adequately fulfilled all the primary purposes for which it was designed. Patients have been able to wear the splint and yet use the hand for ordinary activities, such as writing, eating, and playing the piano. The constant tension which can be exerted by the spring steel has proved the most satisfactory means of correcting severe contractures, previously treated by the cumbersome banjo splint. The plaster accessory has proved a safe and adequate method of splinting, while avoiding the disadvantages of immobilization in cases requiring plaster casts. The splint has been further adapted to correct toe deformities, including drop-toe and claw-toe. The use of a universal model with interchangeable parts has facilitated production and distribution.

AN IMPROVED BONE CLAMP AND A PLATE FOR INTERNAL FIXATION OF FRACTURES

BY JEAN VERBRUGGE, M.D., ANTWERP, BELGIUM

The bone clamp devised by the author (Fig. 1) has the following characteristics and advantages: It is made of stainless steel. At one end there is a ratchet and narrow teeth, which permits a wide range of motion. The shaft has sufficient elasticity to make possible its manipulation with two fingers only. The distal end is slightly curved, so as to facilitate the handling of the instrument and yet not interfere with subsequent drilling or

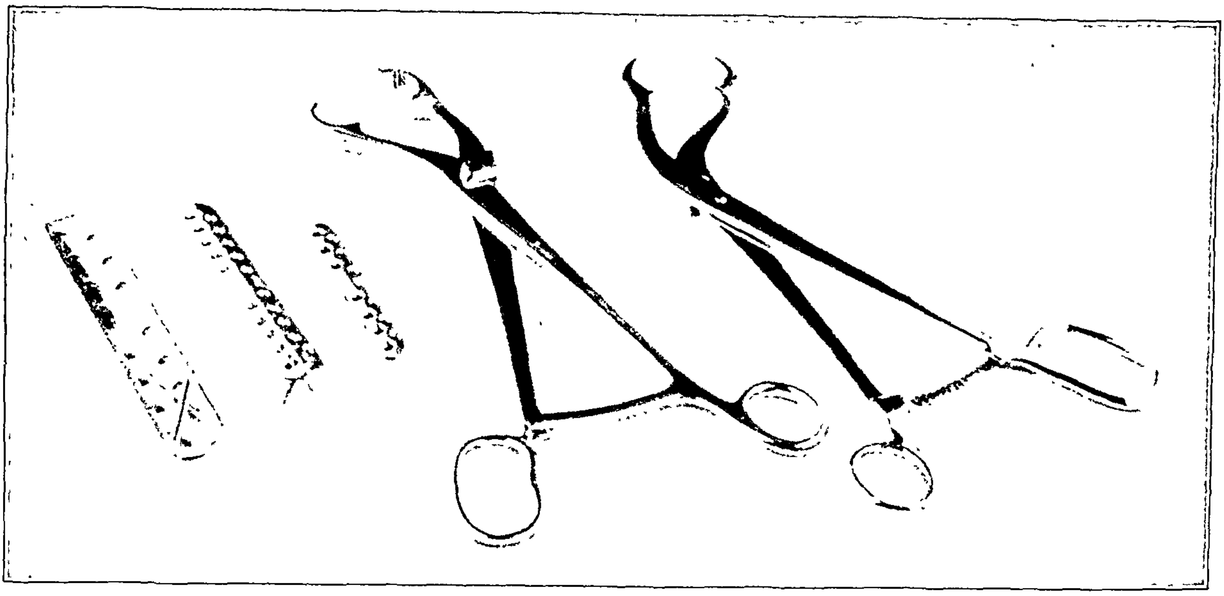

Fig. 1

Plates for fixation of femur, humerus, and bones of forearm or clavicle, showing the arrangement of screws; and bone clamp, shown from both sides.

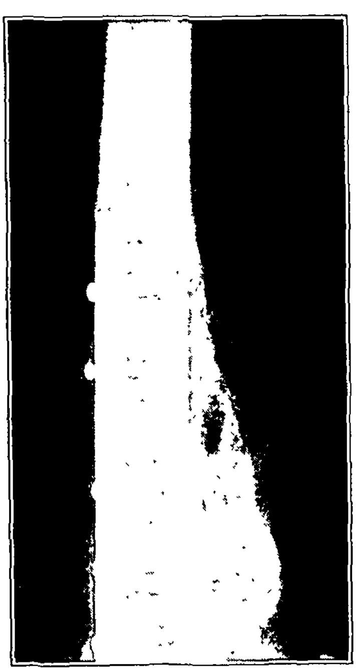

Fig. 2

Fig. 2. Plating of a femur for shortening of the lower limb (twelve centimeters). Note that all the screws are of the same length.

screwing. The clamp can be operated with one hand like a Kocher clamp, which facilitates the prehension of bone and helps in the fixation of a plate or a graft on the shaft. The bone clamp is made in three sizes—one for the femur, one for the humerus, and one for the bones of the forearm or the clavicle.

The plate was devised to ensure solid and durable fixation of bony reduction, and was constructed to meet the following requirements:

The plate should be thick in order not to bend. It should be long enough to extend well beyond the site of fracture, since the bone is more demineralized at the end of the fragments. It should be large enough to be solid and not to require the use of a second plate. It should be slightly curved transversely to approximate the shape of the bone. The holes should be placed alternately, so that the screws will be directed at an angle and not parallel to one another. The screws must not be large, so that as many as possible may be used to increase the surface of contact between metal and bone. The plate should be made of a metal which will be inert and at

the same time will bend without breaking, so as to be adjusted to the surface of the bone at the time of operation.

The following dimensions have been adopted for the plate: For the femur, twelve, fourteen, sixteen, eighteen, twenty, and twenty-two centimeters in length; two millimeters in thickness; and twenty-one and one-half millimeters in width. For the humerus, ten, twelve, and fourteen centimeters in length; two millimeters in thickness; and fifteen millimeters in width. For the forearm, four, five, six, eight, ten, twelve, and fourteen centimeters in length; one and one-half millimeters in thickness; and ten millimeters in width.

The dimensions of the screws are as follows: For the femur, two and one-half millimeters in diameter and from twenty-six to forty millimeters in length. For the humerus and forearm, two and one-half millimeters in diameter and from ten to thirty millimeters in length.

The plate and screws were devised in 1943 and the bone clamp in 1944, and the author has used them since then, without any inconvenience.

A SIMPLE TRACTION DEVICE FOR THE REDUCTION OF FRACTURES OF THE FOREARM

BY ROBERT M. ROSE, M.D., NEW ORLEANS, LOUISIANA

From the Tulane Orthopaedic Service, Charity Hospital of Louisiana at New Orleans*

The fundamental principle of traction and countertraction in the reduction of fractures of the forearm has been well established. Various methods have been used and described, from the manual application of traction by the surgeon, alone or assisted, to elaborate apparatus employing Japanese finger traps or wire finger baskets.[1] The device shown in Figure 1 maintains even, continuous traction during the reduction of fractures of the forearm, and it is extremely easy to construct and to use. Since its introduction in May 1942, from eighty to ninety surgeons at Charity Hospital of Louisiana have used this apparatus in reducing over 1,500 fractures of the forearm.

The device consists of two crossbars that clamp to a table top and project on one side for a distance of twelve inches. Covering the bars is a table pad. The patient is placed in the supine position; the head rests on the upper bar, with the upper arm parallel to the upper bar and about four inches from it. Over the anterior surface of the upper arm is placed a felt pad, and a three-inch gauze bandage is wrapped about the arm and the upper bar. This constitutes the fixed point of countertraction. The elbow is then bent at a right angle, and traction is applied to the thumb by means of a single loop of doubled three-inch gauze bandage, approximately three feet in length (Fig. 2). To this gauze loop is fixed a length of sash cord, which passes through the pulley attached to the under surface of the lower bar by means of a removable metal band. Weights on a holder are attached to the distal end of the sash cord, and traction is exerted on the forearm.

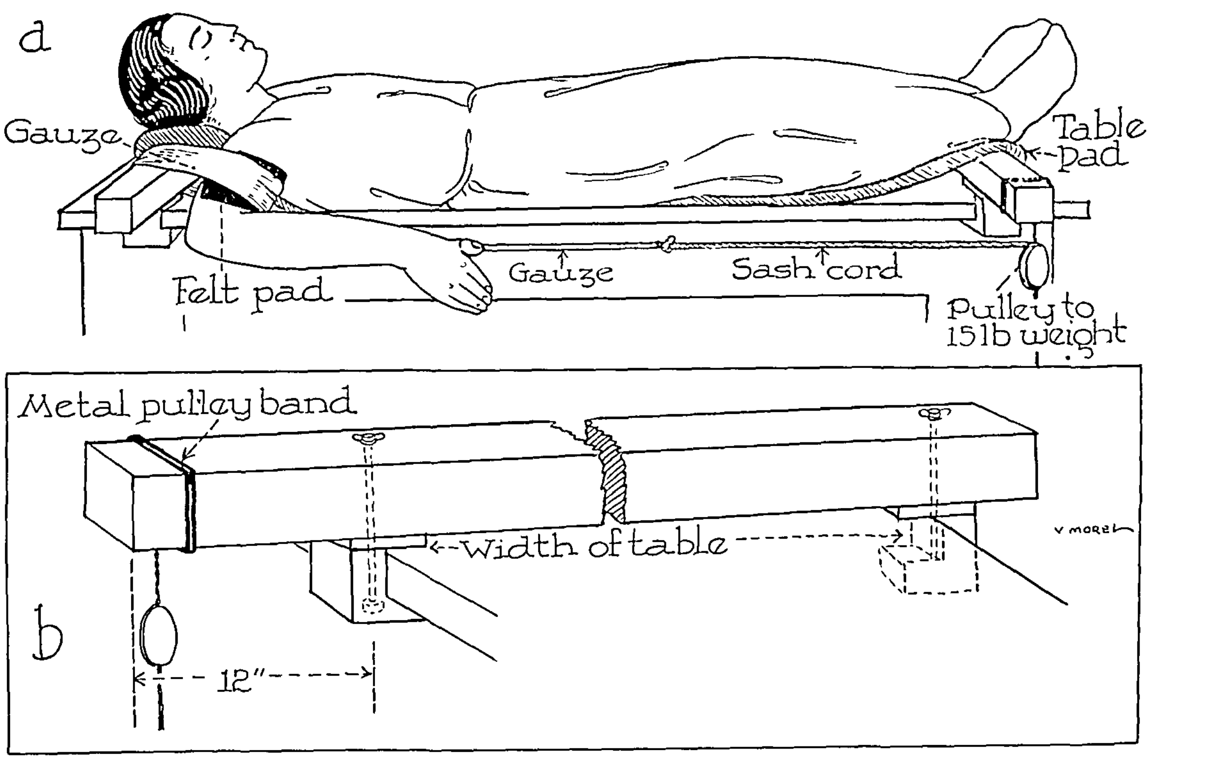

FIG. 1

a: Apparatus for reduction of Colles's fracture of right forearm. If left forearm is fractured, pulley band is placed on upper bar and patient's position is reversed.

b: Detail of construction of lower bar. Pulley band is removable, and may be placed on either bar.

* Service of Guy A. Caldwell, M.D.

There has not been a single instance of circulatory complications following the use of this device, although in a few cases it has been necessary to use twenty-five pounds of traction for thirty minutes. About 80 per cent. of the patients complain of pain in the thumb, if the fracture is reduced under local anaesthesia, but the pain disappears as soon as the traction is discontinued. Padded loops are not recommended, as they slip off the thumb.

The author believes that this device offers the following advantages:

1. The manipulative strength and sensitivity of the surgeon are not lessened by the use of his own hands for traction.

2. The device is simple and inexpensive of construction, extremely adaptable, and, if properly used, foolproof.

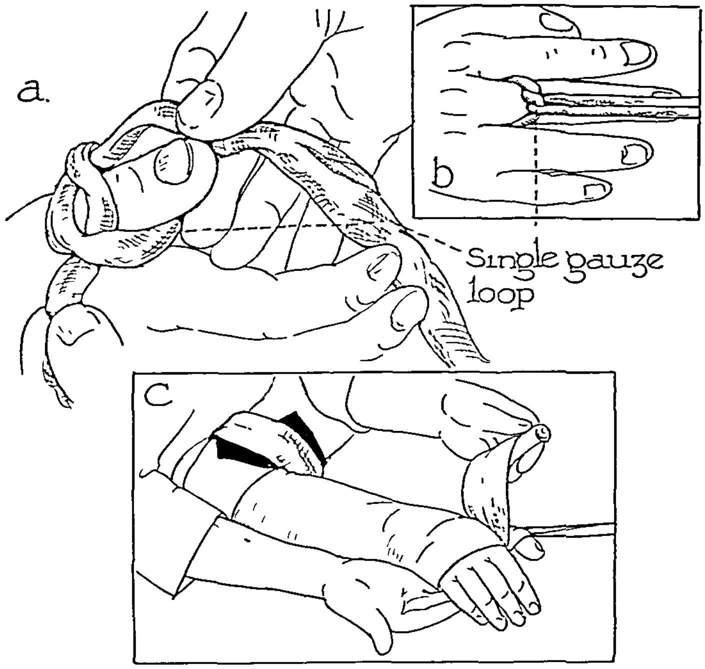

Fig. 2

a: Method of applying single-knot gauze loop about thumb for traction on forearm in functional position.

b: Gauze loop placed about long finger for traction in line with axis of both bones.

c: Illustrates ease of applying cast with traction device in place. After cast to forearm has set, arm may be removed from traction device and cast may be extended above elbow.

3. Many fractures are reduced with traction alone, although impaction of fragments is routinely broken up before traction is applied.

1. Joldersma, R. D.: Traction Reduction of Fractures About the Wrist. Surg. Clin. North America, **23**: 1613–1622, 1943.

A NIGHT SPLINT FOR THE CORRECTION OF GENU VALGUM

BY H. WRIGHT SEIGER, M.D., SANTA MONICA, CALIFORNIA

The occurrence of knock-knee in children is far more common than is usually supposed. Genu valgum in children does not always disappear automatically. If, after a period of observation, it is apparent that growth and the correction of faulty foot mechanics are not sufficient to overcome the deformity, the use of braces at night may be indicated.

Lloyd [1] described a night splint, consisting of longitudinal bars bandaged to the lateral aspect of each lower extremity, for the correction of this condition. Girdlestone described a similar splint, but placed the longitudinal bars on the medial aspect of each extremity, and then bandaged both extremities together.

The splint represented in Figures 1 and 2 has the following advantages:

1. The child can sleep on his face, side, or back, instead of only on his back.
2. The construction provides more even pressure, and therefore redness at the pressure points rarely occurs.
3. Since straps and buckles are used, the mother can place the tongue of the buckle in the same hole in the strap each night, although the attending physician should see the splint about once in two weeks, in order to change the tension as the valgum lessens.
4. There is no constriction of the circulation to the extremities.
5. The average child of five years or over can be taught to apply the splint himself.

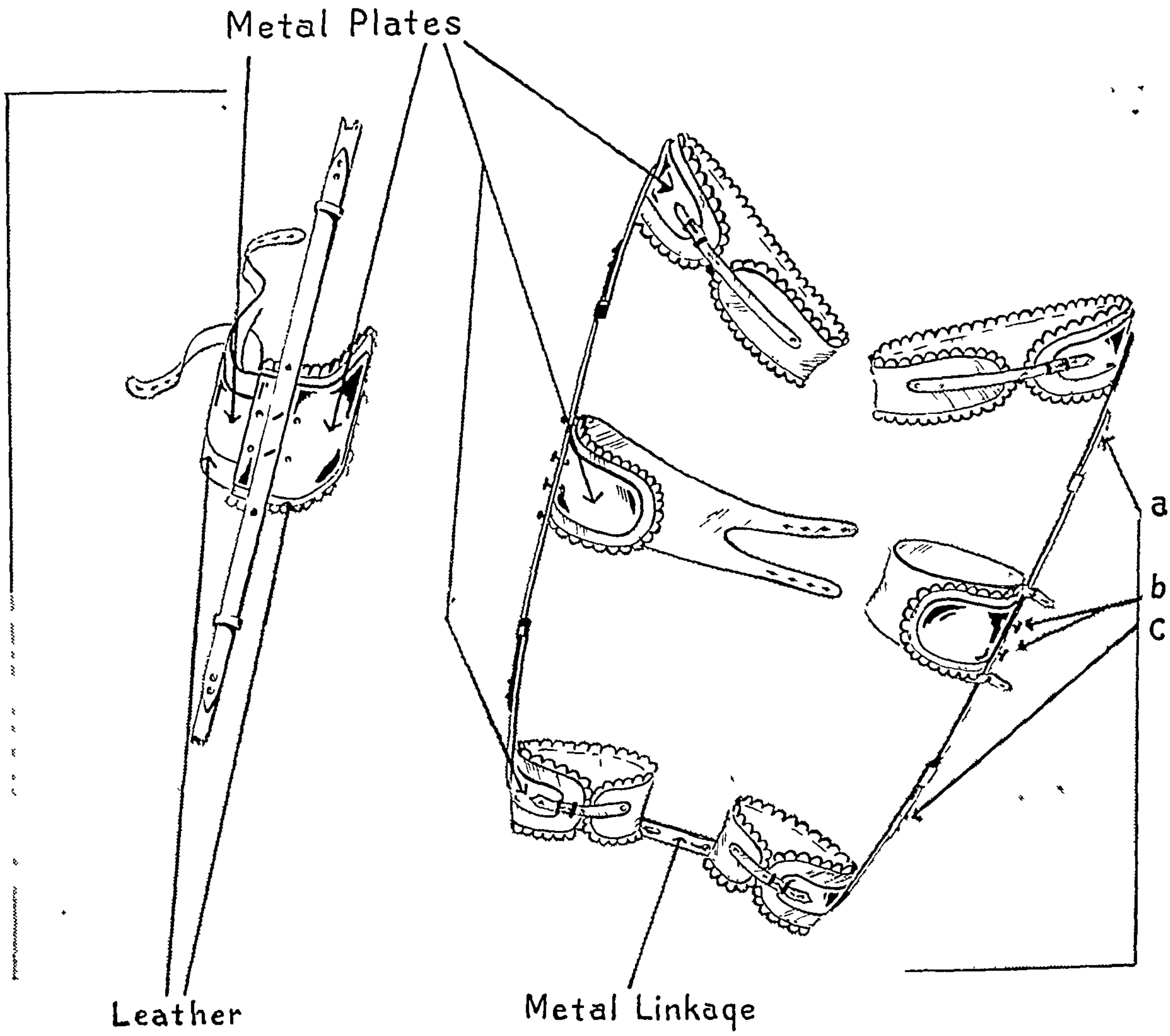

FIG. 1

a and *c*: Screws for adjustment of length of splint.
b: Screws for adjustment of height of plate over knee

6. The splint is adjustable and can be used for children of different ages, or for the same child over a period of time. The author feels that this compensates for the fact that it is somewhat more expensive than the Lloyd or Girdlestone splints.

The average patient requires the use of this splint for about three months. Although it may be worn continually for the three-month period, it may also be worn for at least a month, discarded for an indefinite period, then worn for another month, and so on. It is not necessary to wear it tight, nor to attempt too much overcorrection at one time.

The splint may be made of steel, leather, and felt; or, to lessen the weight, may be made of duralumin with straps of felt-covered leather. To increase or decrease the lateral pull at the knees, the lateral rods may be bent slightly as the patient's condition improves.

In supervising the progress of a patient with genu valgum, it is important to keep a record of the reduction of space between the ankles. The record of the intermalleolar distance [2] was found to be a simpler, and probably more accurate, guide to the progress of each patient than the usual method of drawing an outline of the lower extremities.

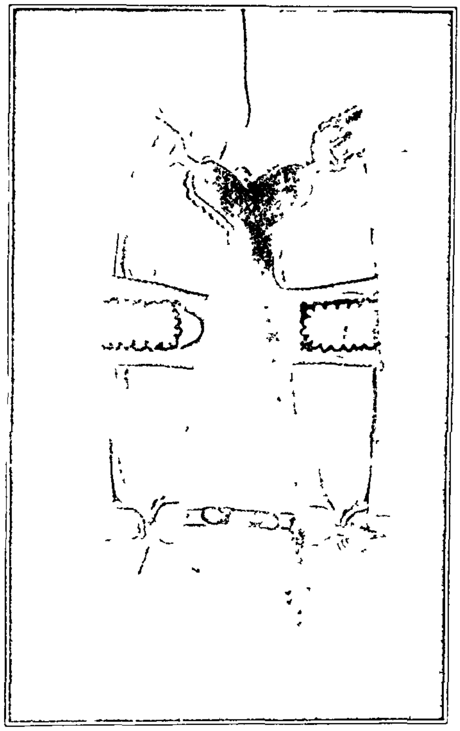

Fig 2
The splint in position.

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1. Lloyd, E. I.: Night Splint for Knock-Knee in Children. British Med. J., 1: 676, 1939.
2. Lloyd, E. I.: Knock-Knees and Bow-Legs. Practitioner, 150: 238–244, 1943.
3. Girdlestone, G. R.: Night Splint for Knock-Knees. Lancet, 1: 312, 1944.

GLASS CLOTH AS A WOUND DRESSING

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The postoperative care of compound wounds, treated by the Orr method, indicates that petrolatum-impregnated gauze is not an ideal substance to use in the packing of such wounds. Changing the dressings is often quite painful to the patient because, in spite of the most careful preparation of the impregnated gauze, granulations will grow through its meshes, causing it to adhere firmly to the wounds. Unless the gauze is packed correctly, the frayed edges will cling to the wound and act as foreign bodies, causing drainage. Improperly packed gauze will act as a plug, damming back the purulent material, instead of as a means of efficient drainage. In most instances, the removal of such gauze causes considerable bleeding.

Petrolatum-impregnated gauze presents well-known difficulties in preparation, sterilization, storage, and transportation, because of the effects of temperature changes on the oil.

Consideration of these factors prompted a desire to find a dressing which would allow proper drainage and granulation of the wound so that an early split-skin graft could be applied, if desired. Such a material should have the following qualifications:

1. It should be non-irritating to the skin.
2. It should not act as a foreign body, if left embedded in human tissue.
3. It should prevent adherence of granulations.
4. It should allow proper drainage of the wound.
5. It should prevent exuberant granulation, yet allow the wound to fill in gradually by granulation, if that method of healing is desired.
6. It should not be painful to remove.
7. Its removal should not cause excessive bleeding.
8. It should be simple to use in packing wounds.
9. It should leave a clean granulating surface so that early skin-grafting may be used.
10. It should be simple to prepare by the personnel of the sterilizing room.

Glass cloth, which from previous experience in animal tissues appeared to be a possible substitute for petrolatum-impregnated gauze, has been used in thirty-five cases to date in circumstances where the gauze was previously employed.

Proper sterilization was obtained by wrapping the material in a cotton towel and placing it in the steam sterilizer for forty-five minutes at a pressure of twenty pounds.

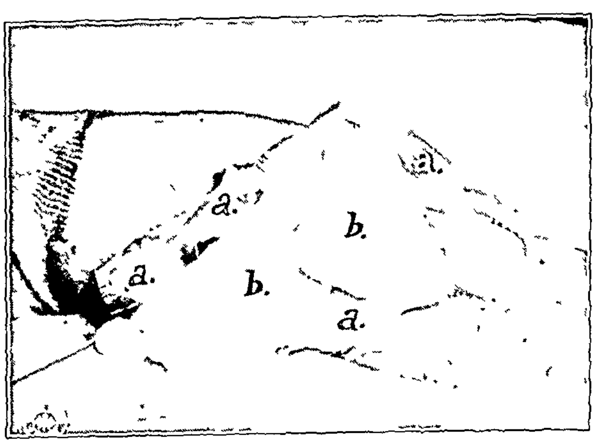

FIG. 1

Dressing applied to saucerized wound of knee. *a*: Glass cloth next to surface of wound. *b*: Dry cotton-gauze wick.

FIG. 2

Forearm wound three weeks after sequestrectomy. *a*: Glass cloth. *b*: Dry cotton-gauze wick. *c*: Exudate from wound absorbed in bulky dressing.

Fig. 3-A

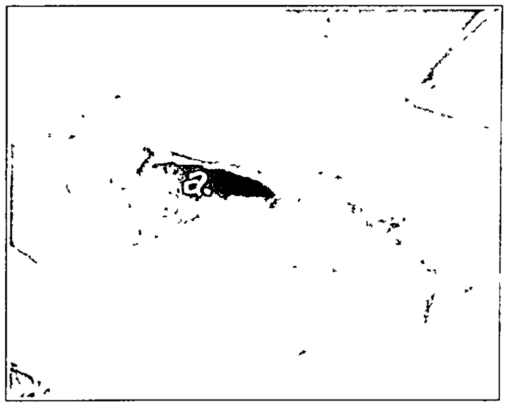

Fig. 3-B

Shoulder wound, three weeks after saucerization of cavity.
Fig. 3-A: Glass cloth on wound surface; no granulations are growing through meshes.
Fig. 3-B: Glass cloth has been removed, showing clean granulations and no bleeding or thick exudate.

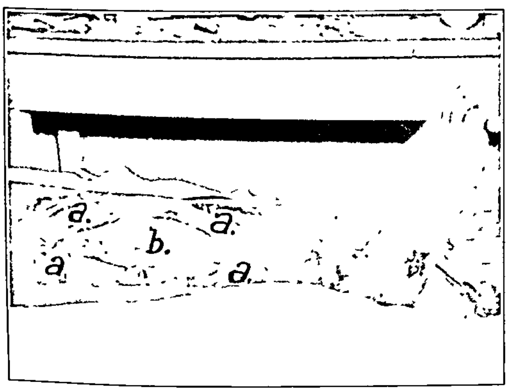

Fig. 4-A

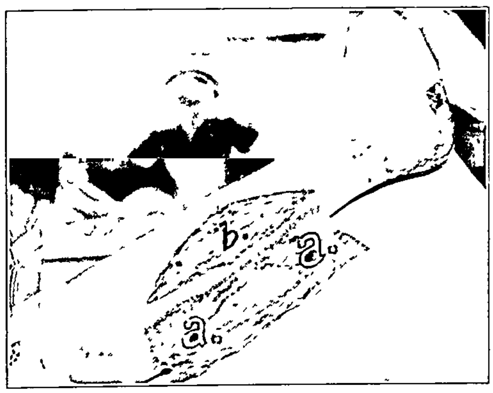

Fig. 4-B

Split-skin graft, ten days after operation.
Fig. 4-A: Glass-cloth dressing forms a smooth stent.
Fig. 4-B: After removal of dressing, showing healed wound.

The material has also been prepared by boiling for ten minutes in the water sterilizer. Although either method is satisfactory, the former is preferred because the material can be stored in the same package until needed.

In applying the dressing at the time of surgery, a square of the glass cloth should be cut, large enough to cover all surfaces of the wound and to project over the skin margin. The center of the invaginated glass cloth should be packed with dry cotton gauze so that the edges of the wound will be held open (Fig. 1). The cotton gauze acts as a wick (Fig. 2) to remove exudate from the wound, and on top of this is placed more cotton gauze to take up the secretions. A pressure bandage or padded cast, as indicated, is placed over such a dressing.

This type of dressing has been left in wounds for varying lengths of time and contra-indications have not been observed. Scholz and Mountjoy[1] reported a suture of similar glass material as inert and non-reacting in tissue.

Figures 3-A and 3-B show a typical wound at the time of dressing.

Glass cloth has been used as the first layer of a wet dressing for a split-skin graft (Figs. 4-A and 4-B).

1. Scholz, R. P., and Mountjoy, P. S.: Fiberglas Suture Material. Preliminary Report. Am. J. Surg., 56: 619–621, 1942.

LOCALIZED BONE CYST OF THE OS CALCIS

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The localized form of osteitis fibrosa cystica, which usually occurs during adolescence, is said to be more common than the generalized form. The common sites are the upper end of the femur, the humerus, and the tibia, although Illingworth and Dick have stated that no bone is immune.

The following case is reported because a cyst occurred in the os calcis. This is not a common site, although McLachlin has reported one such case. The case herein described is typical in that there was no disturbance of the calcium balance.

R.E.D., an airman, aged eighteen, reported on sick parade five days after spraining his left ankle. Clinically, no abnormality of the ankle was found, but the roentgenogram revealed a large cyst of the os calcis (Fig. 1). Roentgenograms of the long bones showed no evidence of other cysts.

On laboratory examination the urinalysis was negative, as was the Wassermann reaction. The erythrocyte sedimentation rate was five millimeters in one hour (method of Westergren). The serum calcium was 11.8 milligrams per 100 cubic centimeters of serum. The inorganic phosphates were 4.7 milligrams per 100 cubic centimeters.

At operation, a small window was made in the lateral aspect of the left os calcis, opening directly into the cyst. The cyst was oval in shape, roughly two inches in length, and one and one-half inches in width at its widest point. It was filled with hemorrhagic fluid which contained fat globules. Very little soft tissue was seen; the walls for the most part were smooth bone. The fluid was drained off, and the soft tissue was curetted out for pathological examination. Twenty-four bone chips from the subcutaneous surface of the left tibia, one-half inch by one-quarter inch by one-eighth inch in size, were placed in the cystic cavity, but were insufficient to fill the cavity completely. After closure a below-the-knee non-weight-bearing cast was applied.

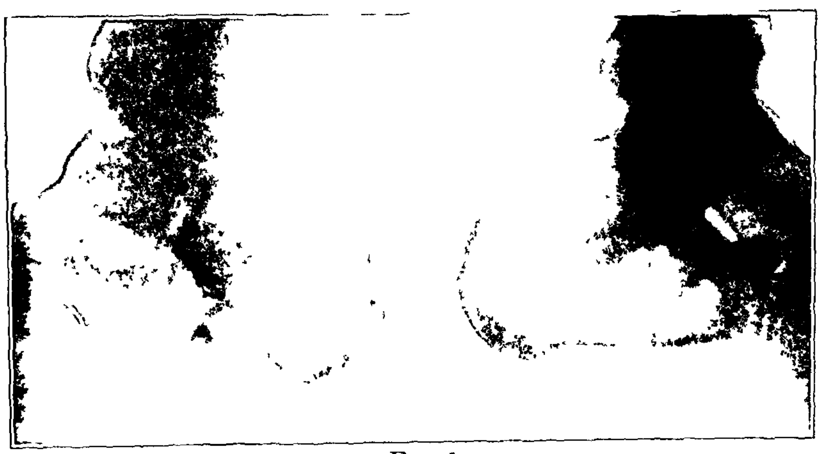

FIG. 1
Cyst of the os calcis.

The pathological report was as follows: "Part of the tissue is of bony character (the piece removed to gain access to the cavity), and the sections show some bone absorption and osteoporosis. Other parts of the specimen are composed of fibrous tissue, and throughout this tissue there are occasional multinucleated giant cells, as well as numerous small cystlike spaces, lined partially by cells which appear to be of the osteoclast type. We consider this to be osteitis fibrosa cystica."

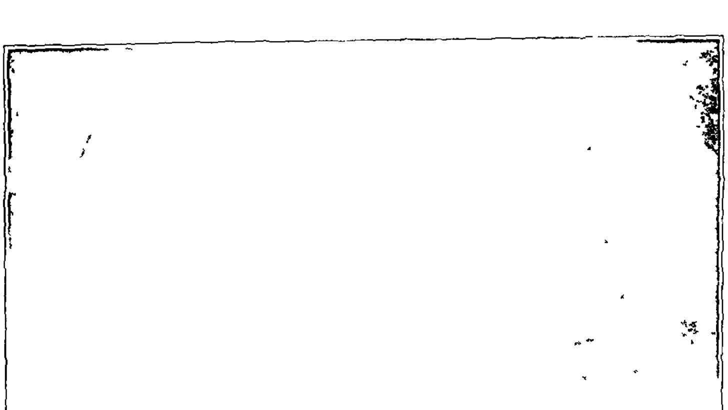

FIG. 2
Five and one-half months after operation.

Ten weeks after operation, a walking plaster was applied. Five and one-half months after operation, the roentgenogram showed bony consolidation of the bone chips (Fig. 2). At this time the patient walked normally and had no complaints; he was therefore discharged to duty.

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A SIMPLE RETRACTOR FOR SPINAL SURGERY

BY G. MOSSER TAYLOR, M.D., LOS ANGELES, CALIFORNIA

From the Department of Orthopaedic Surgery, College of Medical Evangelists, Los Angeles

For many years the retractor most consistently used for spinal surgery has been the one designed by Russell Hibbs for his type of spinal arthrodesis, which requires exposure of the zygapophysial joints. Any assistant who has worked for hours with one of these retractors can testify to the fatigue that results.

A number of retractors have been advanced to simplify the work of interlaminary exploration and removal of a protruded intervertebral disc. Most of them are based upon a screw or ratchet mechanism, however, and are rather complicated.

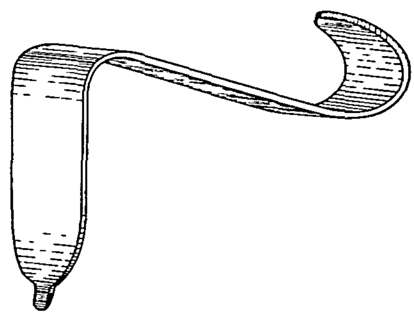

FIG. 1

A number of the newer retractors for general orthopaedic surgery are based upon the principle of leverage, using the bone itself as the fulcrum. The spinal retractor herein described (Fig. 1) is based upon the same idea.

The retractor is made of stainless steel, one-sixteenth of an inch in gauge and one and one-half inches wide; the handle is seven inches long, and the retracting blade is two and one-half inches long for the medium back and three and one-half inches long for the heavier backs.

The important feature of this retractor is the small tip at the end of the retracting blade. The tip is three-eighths of an inch wide and one-half inch long, and is curved slightly forward. The back surface is beveled to a dull edge at the end of the tip.

After the musculature is stripped from the spines and laminae, the lateral facet at the level needing retraction is palpated. The tip of the retractor is then caught on the lateral surface of this facet (Fig. 2), which becomes the fulcrum upon which leverage is made for the retraction of the muscles and the cutaneous tissue.

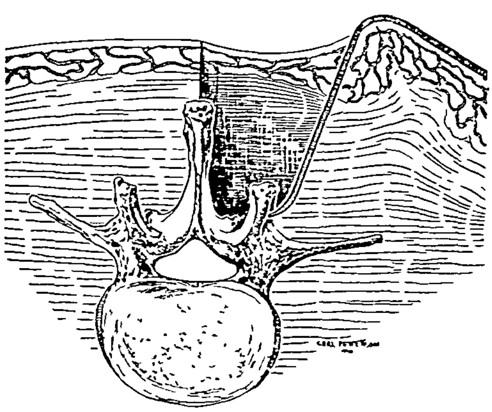

FIG 2

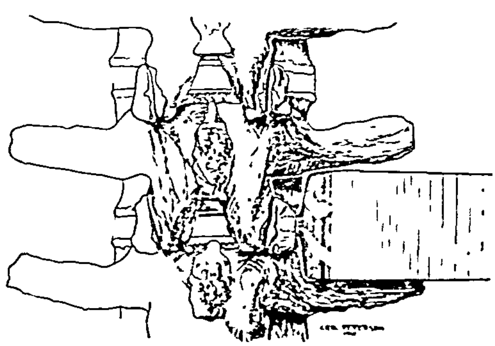

FIG 3

The shoulders of the retracting blade are rounded from the lateral surface of the blade to the beginning of the tip, which makes the retractor more effective in the depth of the wound.

The retractor is flexible enough so that the angle between the retracting blade and the handle can be changed, depending upon the character of the back. The end of the handle is curved upward in a half circle, which makes it easy to support. In the event of incomplete assistance, a loop of sterile bandage can be slipped over the handle and the other end caught under the toe of the surgeon, making the retractor practically self-retaining.

A word of caution must be given, because the leverage exerts a powerful force. If this is maintained too strenuously and for too long a time, the soft tissues may sustain unnecessary pressure necrosis.

The retractor described has been used for the past six months by a number of local orthopaedic surgeons. From their experience, it is believed that the retractor has been of definite aid in simplifying and facilitating a strenuous surgical procedure.

D. MURRAY MEEKISON

1897–1945

D. Murray Meekison died at his home in Vancouver, British Columbia, on October 18, 1945, of coronary thrombosis. In his early death at the age of forty-eight, the Pacific Coast suffers the loss of a leading orthopaedic surgeon.

He was born in Strathroy, Ontario, and moved to British Columbia in 1910; from there he entered the War in 1916, as a private in the University Battalion. He won his commission in the field and was transferred to the Seaforth Highlanders of Canada, a famous Highland Regiment, the pride of Vancouver, which in two wars has brought distinction and fame to Canadian arms. After he graduated in medicine and returned to Vancouver to practise, he became the medical officer of the Seaforths, and remained in that position until 1939, when the regiment went into action again.

Dr. Meekison received the degree of M.B. from the University of Toronto in 1924, and was awarded his B.Sc. the following year. He received postgraduate training in the Hospital for Sick Children, Toronto, and at the Montreal General Hospital. In the Children's Hospital, Toronto, he came under the influence of W. E. Gallie and C. L. Starr, and this determined his future. When he began to practise in Vancouver, it was in the field of orthopaedic surgery, in which he rapidly forged to the front and became a leader among the young orthopaedic surgeons of the Pacific Coast, both Canadian and American. He was President of the Western Orthopaedic Association and a Past-President of the North Pacific Orthopaedic Society; a member of the British Orthopaedic Association; a Fellow of the American College of Surgeons; a Fellow of The Royal Society of Medicine, London; a Fellow of The American Academy of Orthopaedic Surgeons; and a member of The American Orthopaedic Association. At the time of his death, he was Chief of the Orthopaedic Service at St. Paul's Hospital, Vancouver; Chief of the Queen Alexandra Solarium for Crippled Children, Cobble Hill, Vancouver Island; and Chairman of the Orthopaedic Section of the Vancouver Medical Association.

In the field of industrial and traumatic surgery he had a large experience, drawn from the logging and shipbuilding industry of the West Coast. It was he who first recorded the unusual type of fracture of the patella caused when it is driven sideways across the condyles of the femur (tangential osteochondral fracture of the patella). He also had a large practice with crippled children.

Early in World War II (May, 1941) Murray Meekison joined the Royal Air Force Medical Service and became one of the senior surgeons in the highly important and efficient Orthopaedic and Rehabilitation Service organized by Sir Reginald Watson-Jones. He continued in this Service. until he was invalided home two and a half years later. His death was the direct outcome of this illness.

Life was a battle for the accomplishment of high ideals for Murray Meekison, and he shirked not one whit of it. What he attempted he undertook without stint, and he threw into his effort the immense energy of a strong nature. He inherited from covenanting Scotch ancestors a fierce intolerance of wrong, of slipshod work and thinking, and of smug self-satisfaction, which often involved him in strenuous efforts to correct them,—battles which endeared him to his friends and commanded the respect even of those who felt the force of his attack. There was a stern joy for him in attempting to set wrong right.

Though he was one of the youngest members of the Association, he had many friends among the members. The Association by his death has lost a member of sterling character, and shares with his wife and children the hard bereavement.

GUY WHITMAN LEADBETTER

1893–1945

On November 11, 1945, Dr. Guy Whitman Leadbetter, President-Elect of The American Academy of Orthopaedic Surgeons, died in the Emergency Hospital, Washington, D. C., of coronary occlusion. He had been confined to the hospital only a few days and died, as he had lived, without fear, advising his friends that he had no apprehension about his health.

To his friends and associates he typified the "Indestructible Man",—a person endowed with the physical, mental, and temperamental qualities, who should have lived to be a centenarian and not have passed at the age of fifty-one, when his many sterling qualities were being recognized and a future still lay before him. He accomplished much and America has lost one of its most brilliant orthopaedic surgeons.

It is difficult for one to portray Guy Leadbetter to those who did not know him well. Modest and retiring, but always serving with great efficiency and judgment in any task assigned him, be it a local, national, or international problem, he came through with a finished result that was typical of a great man. He had many friends from many walks of life, but only a few knew of his many interests. His church, his professional, and other friends saw only the side of his life in which they were interested.

Born in Bangor, Maine, December 12, 1893, the son of Fred H. and Maude E. Leadbetter, he enjoyed the advantages of the wholesome and rugged life of New England. He entered Bowdoin College and was graduated with an A.B. degree in 1916. In his senior year he was Captain of the Track Team, Captain of the Football Team, established the intercollegiate record for the 16-pound hammer which stood for many years, and was a candidate for the Olympic Team. He was President of his Class and was elected to the Phi Beta Kappa Society. These achievements while at college show the great physical, mental, and personal qualifications of the man. He retained his interest in his Alma Mater and was

a member of the Bowdoin Alumni Council and Chairman of Bowdoin Alumni Association, Chapter of Washington, D. C., and in 1942 was given the honorary degree of Doctor of Science.

He received his M.D. degree from the Johns Hopkins University School of Medicine in 1920. In Medical School he attained a high scholastic standing, engaged in many University and Medical School activities, and was one of the most highly regarded students in his class. While a student, he chose to become an orthopaedic surgeon and received his surgical training at the Lakeside Hospital, Cleveland, Ohio, and his orthopaedic training at the Johns Hopkins Hospital and the Children's Hospital School. He entered private practice in Washington, D. C., in 1923 and became one of the outstanding surgeons of the community and soon earned a well-deserved national and international reputation. Many contributions were the result of his work, the most notable of which was his untiring interest in fractures of the neck of the femur. He was Clinical Professor of Surgery at the George Washington Medical School, Chief of the Orthopaedic Service of the Emergency Hospital, and Consultant to the Children's Hospital and the Casualty Hospital.

His sterling qualifications were recognized early and he was elected a member of The American Orthopaedic Association in 1930 and of The American Academy of Orthopaedic Surgeons in 1934. He also served as Chairman of the Bone and Joint Section of the Southern Medical Association.

Dr. Leadbetter was a man who never shirked a responsibility. He served on the Military Committee of The American Orthopaedic Association and The American Academy of Orthopaedic Surgeons for many years and gave unstintingly of his time to the Office of the Surgeon General. He was appointed Orthopaedic Consultant to the Secretary of War, and Secretary to the Orthopaedic Committee of the National Research Council.

He was an accomplished pianist and had a fine and well-trained baritone voice. He was a linguist, and was proficient in German, Spanish, and French.

Among his other hobbies were astronomy, geology, entomology, scientific photography, anthropology, and archaeology. He gave many lectures on these subjects and compiled an illustrated lecture on "Mayan Ruins at Yucatan". For several years he was the guest lecturer on the Outdoor Program of the National Capital Parks and spoke on a wide variety of subjects as "Death Valley Days", "Bird Life", and "With the Lumber Jacks in the Maine Woods". His interest and work in anthropology was so outstanding that several days after his demise a letter arrived offering him a membership in the Anthropological Society at Albuquerque, New Mexico. He was a forceful speaker, and his spoken and written language were characteristic of his cultural background.

"With all of his stern appearance and serious mind, he was one of the kindest men I have ever known, we shall always miss him",—was the remark of one of his older colleagues with whom he had worked for years.

It was very fitting that such a man should have had an ideal family life. In September 1925 he married Alice Charlotte Johnson, and he is survived by her and their two children, Guy Whitman, Jr. and Patricia Alice.

EUGENIO DÍAZ LIRA

1880-1945

Eugenio Díaz Lira, Chilean surgeon and statesman, died at Santiago, Chile, on June 12, 1945, at the age of sixty-five.

Dr. Díaz Lira studied medicine at the University of Chile, specialized in child surgery and orthopaedics under Broca and Kirmisson in Paris, and then took a course in tuberculous affections at Berck-sur-Mer, under Calot and Menard. Upon returning to his native land, he became the first Professor of Orthopaedic and Infantile Surgery in the University of Chile, and a pioneer in the field.

He conducted the clinics at the Roberto del Rio Hospital for Children for forty years. He founded the Nurses' Training School, and thus pioneered in establishing this profession in Chile. Likewise, he was the founder and President of the Sociedad de Pediatria and the Society of Surgeons. In 1930 he was appointed Director of the School of Medicine of the Catholic University in Santiago. In addition to holding membership in local societies in Chile, Dr. Díaz Lira was a member of the Société Française de Pédiatrie, corresponding member of the Peruvian Society of Pediatrics, a member of the Society of Surgeons of Buenos Aires, and an honorary member of the American Academy of Orthopaedic Surgeons.

The Government of Bolivia conferred upon him the decoration of the *"Condor de los Andes"*, in recognition of his services and professional aid to so many Bolivians and of his invaluable contribution to the mutual understanding of Chileans and Bolivians.

Dr. Díaz Lira is survived by his widow and several children. One son, Eugenio Díaz Bordeu, was associated with his father in the practice of orthopaedic surgery.

ANDREW PRITCHARD MacKINNON

1880-1945

On June 14, 1945, Dr. Andrew Pritchard MacKinnon died in Winnipeg after a long illness.

Dr. MacKinnon was born in North Wakefield, Quebec, but had lived in the Province of Manitoba since 1883. He was educated at Griswold, Portage la Prairie, and Winnipeg, and was graduated from Manitoba Medical College in 1907. After several years of general practice in Portage la Prairie, he went overseas with the Eleventh Canadian Field Ambulance, and returned to Canada in 1918. He worked in the Orthopaedic Wards of the Fort Osborne Military Hospital, and then spent six months in the Manitoba Sanatorium at Ninette, gaining experience in the treatment of tuberculosis. In 1920 he became associated with the late Dr. H. P. H. Galloway, and after the death of Dr. Galloway he headed the MacKinnon Clinic.

Dr. MacKinnon was a Fellow of the American College of Surgeons, a Fellow of the Royal College of Surgeons of Canada, and a Fellow of The American Academy of Orthopaedic Surgeons. He had been President of the Winnipeg Medical Society, and was chief of the Orthopaedic Service at St. Boniface Hospital and lecturer in orthopaedic surgery in the University of Manitoba.

Dr. MacKinnon was a man of the highest principles, and will long be remembered by his patients for his sincerity and his devotion to their interests. He was of kindly disposition, and his passing has left a definite gap in the medical life of Winnipeg.

News Notes

PROGRESS ON GRADUATE TRAINING IN ORTHOPAEDIC SURGERY

Since the statement on Postgraduate Training in Orthopaedic Surgery was published in the October issue of *The Journal of Bone and Joint Surgery,* events have developed so rapidly that now the need for additional residencies for training orthopaedic surgeons has become an urgent demand. Despite the increased number of approved residencies, there is a much greater need than was anticipated. Many heads of services have reported a large number of applicants. Our plan to have a registry established for orthopaedic residencies and applicants has not been realized simply because personnel could not be found to handle the work. It is hoped that within a few weeks such a registry will be established.

A good many services have not been able to execute their reorganization plans as yet, but should be ready for additional residents within the next six months. In a good many instances, residencies are being held for men who had partially completed their training before entering the Army. The uncertainty about the time of discharge for some of these men leaves some residencies unfilled at this time. Other men who have applied in advance of their release have been put off until such time as their dismissal date is known.

Additional services for training residents will be certified in the near future, and it is hoped that others will be developed in communities where the committee feels adequate facilities and personnel are available. Expansion of already existing services will be possible in some instances, but it appears that there will not be enough services to satisfy the demand.

In planning new services some lack of understanding has been evident regarding the amount of training in the basic sciences necessary to qualify for the examinations of The American Board of Orthopaedic Surgery. Much has been written and spoken about this phase of training, but it was evident that a more definite proposal was necessary to clarify the Board's position. To this end the Board prepared the following statement:

Plans for Basic Science Training

Preamble

It is fundamental that directors of hospitals and medical schools should recognize the importance of training in the basic sciences. Residents should be released from hospital duty for the time necessary to take these courses, and the medical school faculty and visiting staff should provide the necessary facilities and instructors. The Board has specified that six months, or approximately one sixth of the total three-year resident-training period, should be devoted to the basic sciences,—anatomy, pathology, physiology, and biochemistry and bacteriology. In those institutions approved for two or three years of resident training, integration of the work in the basic sciences with clinical training is desirable, *provided* the working schedules for residents are arranged to allow sufficient free time to be equivalent to six months of undivided time.

If matched training is acquired in several different institutions or in localities where adequate facilities do not exist, a minimum of six months of undivided time should be devoted to instruction in basic sciences.

During the limited time allowed, residents should study that portion of each subject related to efficient practice of orthopaedic surgery. The trainees should not be expected to become competent assistants in the departments of anatomy and pathology. On the contrary those departments should have the necessary instructors and facilities to help the trainees acquire the required knowledge.

Therefore, the suggestion is made that the basic sciences be taught primarily by members of the orthopaedic staff, with assistance from instructors of the basic sciences as indicated.

Basic Science Training

I. *Pathology*: Perhaps forty per cent. of the training period should be devoted to pathology. This should include pathology of joint diseases, bone tumors, various diseases of bone, soft-tissue tumors, and other diseases, and such general pathology as is germane to the subject.

The aim should be to establish, under supervision of the orthopaedic staff and residents, orthopaedic museums which would include gross specimens, microscopic slides illustrating the most important lesions, and case records covering the above.

II. *Anatomy*: It is felt that approximately forty per cent. of the time in basic sciences should be spent in anatomy. Cadavera, when available, moulages, and preserved specimens and skeletons should be provided for this study. Instruction in operative exposures should be

given by an orthopaedic staff member utilizing this anatomical material. Instruction should also be given in the relation of anatomy to body mechanics.

III. *Bacteriology*: Approximately ten per cent. of the time should be spent in the clinic application of bacteriology. The study of the relation of bacteriology to wound healing, tl flora of wounds, gross infections, and the relation of antibodies and treatment of wounds chemotherapy, and a review of the subject of virus diseases should be included.

IV. *Physiology and Biochemistry*: Again, we suggest that ten per cent. of the time f basic sciences be allotted to these subjects. Seminars should be conducted on shock, flu balance, electrolytes, blood substitutes, acids, calcium and phosphorus, metabolism, and tl chemistry of joint fluids.

V. Seminars or conferences are considered most suitable for the review of this subjec

From this it should be clear that the review of the basic sciences may be given in the form of a si months' course, or it may be spread through the training program. It is suggested that the entire or thopaedic staff should take part in the training program; they themselves will benefit from such pa ticipation.

In some communities the shift of patients from hospital services and out-patient clinics to the ca of private specialists has left hospital services short of material for training purposes. Anticipating such a state of affairs, last January the Board passed the following resolution:

"In special instances, with the approval of the Committee on Resident Training, the Board wil recognize for not over two years' training in orthopaedic surgery periods of training in which the can didate combines work in a hospital service with part-time assistantship to an orthopaedic surgeon cer tified by The American Board of Orthopaedic Surgery, provided that the major part of his time is spen in the hospital service."

In order to make such a service acceptable, a description of the hospital and office services with ar outline of the proposed schedule for work should be filed with the Board.

A registry has recently been established, and it is suggested that from now on all persons seeking appointments to residencies and all heads of services seeking men to fill their residencies contact Dr A. R. Shands, Jr., Box 269, Wilmington, Delaware.

There will be a booth at the meeting of The American Academy of Orthopaedic Surgeons in January 1946, where information regarding residencies can be exchanged.

R. K. Ghormley, M.D., Chairman

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Thirteenth Annual Convention of The American Academy of Orthopaedic Surgeons will be held at the Palmer House, Chicago, January 20, 21, 22, and 23, 1946, under the presidency of Dr. E. Bishop Mumford.

Registration will begin at ten o'clock, Saturday morning, January 19. During the afternoon, motion pictures will be presented, and in the evening the Instructional Section Dinner will be served. The program for the evening will include a panel discussion of "The Painful Shoulder and Upper Extremity".

The Scientific, "New Ideas", and Technical Exhibits may be visited on any of the Convention days, and several programs of motion pictures have been planned.

The program prepared by the Sub-Committee on Instructional Courses includes a series of teaching periods, dealing with fundamental topics related to orthopaedic surgery. The regions to be covered this year are: (1) The Foot and Ankle; (2) The Knee; (3) The Hip; and (4) The Shoulder. The Courses are as follows:

COURSE I. THE FOOT AND ANKLE

Orthopaedic Anatomy of the Foot and Leg.	Theodore A. Willis, M.D.
Symptoms, Pathology, and Diagnosis.	Lenox D. Baker, M.D.
Diseases of the Foot and Ankle with Special Reference to Treatment.	J. Warren White, M.D.
Treatment of Traumatic Lesions of the Foot and Ankle.	Harry Winkler, M.D.

COURSE II. THE KNEE

Orthopaedic Anatomy of the Knee.	Allen F. Voshell, M.D.
Symptoms, Pathology, and Diagnosis.	Robert V. Funsten, M.D.
Diseases of the Knee Joint.	J. Albert Key, M.D.
The Treatment of Traumatic Lesions of the Knee Joint.	John R. Cobb, M.D.

COURSE III. THE HIP

Orthopaedic Anatomy of the Hip.	John J. Fahey, M.D.
Symptoms, Pathology, and Diagnosis.	A. Bruce Gill, M.D.
The Treatment of Diseases of the Hip Joint.	Alan DeForest Smith, M.D.
Traumatic Hip Lesions with Special Reference to Treatment.	Lawson Thornton, M.D.

COURSE IV. THE SHOULDER

Orthopaedic Anatomy of the Shoulder.	Major J. E. Milgram, M.C.
Symptoms, Pathology, and Diagnosis.	Toufick Nicola, M.D.
Treatment of Non-Traumatic Lesions of the Shoulder.	David M. Bosworth, M.D.
Treatment of Traumatic Lesions of the Shoulder Joint.	Harrison L. McLaughlin, M.D.

COURSE V. PHYSIOLOGY

Physiology of Bone in Health and Disease.	C. H. Hatcher, M.D.
The Orthopaedic Physiology of Nerves.	Edward L. Compere, M.D.
Physiology of Muscle.	Eben J. Carey, M.D.
The Normal and Pathological Anatomy and Physiology of Articular Structures.	Granville A. Bennett, M.D.

COURSE VI. ORTHOPAEDIC X-RAY

The X-Ray Investigation of Certain Orthopaedic Problems.	S. A. Morton, M.D.

COURSE VII. INFANTILE PARALYSIS

The Treatment of Anterior Poliomyelitis in the United States: History and Development.	Ralph K. Ghormley, M.D.
Present Methods of Treatment in Anterior Poliomyelitis.	William T. Green, M.D.

COURSE VIII. PRINCIPLES OF FRACTURE MANAGEMENT

Principles of Fracture Treatment.	Paul B. Magnuson, M.D.

COURSE IX. CONSERVATIVE TREATMENT OF LOW-BACK SYNDROME

The Conservative Treatment of the Low-Back and Sciatic Syndrome.	E. M. Regen, M.D.

COURSE X. CEREBRAL PALSY

Cerebral Palsy.	W. M. Phelps, M.D.

COURSE XI. POSTURE

Posture.	Captain Frederick A. Jostes, M.C.

COURSE XII. CLUB FEET

Treatment of Congenital Club-Foot.	J. H. Kite, M.D.

COURSE XIII. FRACTURES OF SHAFT OF FEMUR

Treatment of Fractures of the Shaft of the Femur.	Guy A. Caldwell, M.D.

The Monday morning session will be devoted to a Symposium on Degenerative Hip Disease:

Etiology and Pathology of Degenerative Hip Disease.	Dallas B. Phemister, M.D.
Conservative Treatment.	Paul C. Colonna, M.D.
Arthrodesis of the Hip Joint for Degenerative Hip Disease.	G. Edmund Haggart, M.D.
Arthroplasty of the Hip for Degenerative Hip Disease.	Carl E. Badgley, M.D.
Drilling Operation and Summary.	Melvin S. Henderson, M.D.

On Monday, Tuesday, and Wednesday the Scientific Program will be presented, and Academy Luncheons will be held at one o'clock on each of those days. There will be Executive Sessions at noon on Monday and on Wednesday. The following program has been announced by the Program Committee, Dr. Robert W. Johnson, Jr., Chairman:

MONDAY, JANUARY 21

Afternoon Session

Combined Neurectomy and Bone Graft in Spastic Torticollis.
Alfred W. Adson, M.D., Rochester, Minnesota.
H. Herman Young, M.D., Rochester, Minnesota.
Ralph K. Ghormley, M.D., Rochester, Minnesota.

Sympathetic Block of the Stellate Ganglion: Its Application in Orthopaedic Conditions.
Guy A. Caldwell, M.D., New Orleans, Louisiana.
T. F. Broderick, M.D.
R. M. Rose, M.D.
The Operative Treatment of Scoliosis—A Corrective Appliance Supersedes the Bent Cast.
Walter P. Blount, M.D., Milwaukee, Wisconsin.
Albert C. Schmidt, M.D., Milwaukee, Wisconsin.
Segmentations During Contraction of Mammalian Skeletal Muscle.
J. E. Markee, M.D., Durham, North Carolina.
H. Lowenbach, M.D., Durham, North Carolina.
Use of the Three-Flanged Nail in Knee Fusion.
David M. Bosworth, M.D., New York, N. Y.

TUESDAY, JANUARY 22

Morning Session
Indications and Results from Mold Arthroplasty and Other Plastic Operations on the Hip.
Paul H. Harmon, M.D., Milton, West Virginia.
Arthrodesis of the Hip, Brittain Type.
Joseph A. Freiberg, M.D., Cincinnati, Ohio.
Treatment of Congenital Dislocation of the Hip.
Edward L. Compere, M.D., Chicago, Illinois.
Mobilization of the Metacarpophalangeal Joints—Arthroplasty and Capsulotomy.
Captain Samuel B. Fowler, M.C., A.U.S.
Psychological Problems Observed in Military Orthopaedic Surgery.
Major J. Vernon Luck, M.C., A.U.S.
Factors Influencing Bone Repair in Open Reductions of Fractures.
Jean Verbrugge, M.D., Antwerp, Belgium.

Afternoon Session
Treatment of Compound Comminuted Fractures of the Elbow Joint by Resection of Fragments.
Commander J. T. Nicholson, M.C., U.S.N.R.
Restoration of Bone Strength with Reinforcement Bone Grafts.
Lieutenant Colonel George K. Carpenter, M.C., A.U.S.
Major Robert T. Rosenfeld, M.C., A.U.S.
Major Karl F. Mech, M.C., A.U.S.
Reconstruction of Defects of Tibia and Femur with Apposing Massive Grafts from the Affected Bone. A Preliminary Report.
Major John J. Flanagan, M.C., A.U.S.
Captain Henry S. Burem, M.C., A.U.S.
Skin Grafting in the Treatment of Osteomyelitis.
Lieutenant Colonel Robert P. Kelly, M.C., A.U.S.
Overseas Treatment of Compound Fractures of the Long Bones.
George O. Eaton, M.D., Baltimore, Maryland.

WEDNESDAY, JANUARY 23

Morning Session
Neurectomy to Produce Atrophy of Amputation Stump.
Alfred O. Adams, M.D., Spokane, Washington.
Conservation of Short Amputation Stumps by Utilization of Tendon Section.
Lieutenant Colonel Harry C. Blair, M.C., A.U.S.
Major Harry D. Morris, M.C., A.U.S.
The Technique of the Syme Amputation.
Major R. H. Alldredge, M.C., A.U.S.
Lieutenant Colonel T. C. Thompson, M.C., A.U.S.
Amputation of Upper Extremity.
Captain H. H. Kessler, M.C., U.S.N.
Amputations of the Lower Extremity.
Commander D. D. Toffelmier, M.C., U.S.N.R.

Afternoon Session
Disability Evaluation of the Hand.
Major Donald B. Slocum, M.C., A.U.S.
Captain Donald R. Pratt, M.C., A.U.S.

Cellophane in Reconstructive Orthopaedic Surgery.
Duncan C. McKeever, M.D., Houston, Texas.
Operative Creation of New Gliding Channels for Tendons and Muscle Bellies.
Major J. E. Milgram, M.C., A.U.S.
The Repair of Knee Ligaments by Cutis Graft Transplants.
Randolph L. Anderson, M.D., Charleston, West Virginia.
Semi-Delayed Bone Graft for Subcapital Fractures of the Hip.
Arch F. O'Donoghue, M.D., Sioux City, Iowa.

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Annual Meeting of the British Orthopaedic Association was held at the Royal College of Surgeons of England on October 26 and 27, 1945.

Mr. St. J. D. Buxton, in his presidential address, reviewed methods of preventing accidents, and stressed the importance of teaching first aid. Fatal industrial accidents have decreased in number, but there has been a steady increase in all reported accidents in recent years, particularly in injuries of the feet and hands. The financial cost and loss of production resulting from industrial accidents in England have been estimated as seventy million pounds a year. Propaganda is needed for the further education of the workman in safety-consciousness. Members of the Association were urged to aid in preventive work by inquiring as to the exact causation of accidents, and to effect closer cooperation with those concerned with industrial medicine. The surgeon's aim is to return the injured man to his work in a fit condition as soon as possible, and to reduce disability to a minimum. During treatment, the patient must be kept fit mentally as well as physically. A nationwide accident service is required, especially for industrial and road accidents.

Professor T. P. McMurray gave an interesting account of the historical background of Hugh Owen Thomas, and described the classical splint which Thomas and his disciples called the "bed knee splint". The efficiency of this appliance, which Thomas evolved in his own workshop, was emphasized. Almost all of the improvements and alterations since made in this splint had been tried out by Thomas and discarded. The details of construction, measurement, and application of the splint were described. The simplicity of the original design meant that there was little to get out of order.

Congenital Dislocation of the Hip

Professor J. Leveuf, of Paris, described his investigations, based upon arthrography and operative findings, which showed that there was a complete difference between congenital subluxation and congenital dislocation of the hip. He disagreed with the generally accepted view that subluxation is a preliminary stage, leading to dislocation. In arthrograms of dislocation, the limbus produced by the upper portion of the cotyloid ligament or cartilage was visualized as a downward projection, causing the usual hour-glass contraction; in subluxation this shadow was never found, for the limbus was pushed upward and was compressed against the ilium. In dislocation the head of the femur was small and the ligamentum teres persisted; in subluxation the femoral head was large and the ligamentum teres was absent. There was no other interposition of soft tissue in subluxation. Anteversion of the femoral neck was an early finding in subluxation; it was a late or secondary deformation in dislocation. In discussing treatment of this condition, Professor Leveuf stressed the need of getting a hip in which the femoral head conformed to the acetabulum. Closed reduction was only suitable under the age of two years; after this age he favored operation. In those cases requiring reconstructive work to restore the bony conformation, he favored a transtrochanteric intra-articular approach, in which osteotomy of the femoral neck was carried out, if necessary, and the acetabulum was deepened by turning down its roof and inserting a graft above it.

Mr. J. S. Batchelor reviewed the problem from the point of view that congenital dislocation of the hip was an external rotation-adduction deformity with three stages of severity. Treatment consisted in correction of soft-tissue contracture by gradual abduction, followed by manipulative reduction and reversal of the deformity with encouragement of normal development by function. For this purpose he used knee plasters joined together by a crossbar; the hips were held in abduction and internal rotation, but were otherwise free to move in flexion and extension. For cases showing redislocation, anteversion, and valgus of the femoral neck, osteotomy to reduce these deformities was carried out after the femoral head had been replaced in the acetabulum.

Mr. H. A. T. Fairbank remarked that Professor Leveuf appeared to do open operations more often than was thought necessary in England, yet his results were excellent. Hitherto Mr. Fairbank had thought that the problems of anteversion and valgus had been overstressed; evidently he was wrong. Anterior transposition or anterior dislocation, he thought should be left alone, since patients with this condition walk very well.

Professor Harry Platt, speaking from more than thirty years' experience with nearly 500 cases,

strongly supported Professor Leveuf's view that subluxation and dislocation were two distinct morphological entities. He also believed that the femoral heads were naturally placed posteriorly in many cases and anteriorly in others. He denied that the former could be forced into the latter position, and he also believed that the position of marked internal rotation was dangerous for fixation.

Mr. G. R. Girdlestone expressed anxiety over the risks of avascular changes in the femoral head after extensive intra-articular operations.

Sir Reginald Watson-Jones, supporting Professor Platt's views, thought that there were many morphological types. He distinguished three main types from the point of view of treatment. The first group included those hips which were reduced in full abduction, and after a year remained reduced. In the second group, after a year of abduction, the hip tended to subluxate soon after the patient was allowed to kick about in bed. In the third group, despite full abduction, the heads were never fully replaced in the acetabula. The second and third groups required operative treatment, and patients in the third group should be recognized early and operated upon promptly. He believed that there was less risk of osteo-arthritis in cases with incongruity of capital and acetabular form than there was in those with avascular changes in the femoral head. For this reason he felt that a long period of observation was needed before Professor Leveuf's results could be judged.

Mr. B. L. McFarland regarded anterior transposition as meaning the riding of the femoral head under the rectus tendon and Y-shaped ligament; it was not a complete anterior dislocation. The more he had seen of acetabuloplasty, the less satisfied was he with the results. Remolding of the hip joint was dependent upon the proper direction of the thrust of the femoral head into the acetabulum; therefore he advised maintenance of abduction during the early walking stages of treatment.

Miss Maud Forrester-Brown urged the importance of the functional care of muscular activity.

Professor Leveuf, in reply, said that true dislocation was more difficult to reduce by non-operative methods; the case of "reduction" in subluxation was deceptive and the results by this method were likely to be disappointing. If the hip was left in a state of subluxation, osteo-arthritis would be certain to occur. He stressed the value of the arthrogram, not only for diagnosis, but also as the most satisfactory test for reduction. He was convinced of the value of his complete operation. In 202 cases in which he had done open operations, he had had only one case of necrosis of the femoral head. The secret was that there was no interference with the blood supply which entered the femoral head from the soft tissues below the femoral neck.

Mr. Batchelor remarked that his method of holding the hip joints, while allowing movement, ensured the maintenance of extension as well as of flexion. He had had no trouble with stiffness, resulting from the internally rotated position. The happiness and comfort of the patients was noteworthy. If stiffness occurred, it was due to mismanagement.

Orthopaedics in Medical Education and in Regional Hospital Services

Starting with the definition of Robert Jones that orthopaedics is "the treatment by manipulation, operation, re-education, and rehabilitation, of the injuries and diseases of the locomotor system", Professor Harry Platt of Manchester reviewed the evolution of specialism in surgery, or differentiation, as a changing pattern. There are two fundamental requirements: each surgical specialty must continue to advance the general craftsmanship of surgery, and—of even greater significance—it must contribute to general ideas. Richness of technological advances does not compensate for poverty of ideas or of vision. The recruitment of men and women, trained in scientific and historical methods and with high standards of scholarship, is needed for the preservation of vitality in the differentiated fields. Professor Platt regarded abdominal surgery as the "romantic" movement in surgery, with its growth during the twentieth century; orthopaedics, embracing a large part of the general surgery practised by the nineteenth-century surgeon, he regarded as being rooted in the classical period. The automatic right of the abdominal surgeon to assume leadership in the affairs of surgery can no longer be admitted. A plea was made for more satisfactory integration of undergraduate teaching in orthopaedics,—not to instill the details of complicated techniques, but to introduce and to explain to the student the clinical phenomena of the disorders of locomotion, the biological and social background of crippling disease, and the ancient therapeutic methods of rest, fixation, and purposive movement. Orthopaedic teaching must permeate the undergraduate course. In postgraduate education three types of instruction were considered: the training of the orthopaedic surgeon of the future; postgraduate instruction of the short intensive type; and training for higher degrees or diplomas in orthopaedics, the desirability of which was doubted.

In the Regional Hospital Service of the future, the orthopaedic services were envisaged as of two types. In an area with a population of 150,000, one orthopaedic-accident surgeon would be associated with two general surgeons in the key hospital, his time being devoted predominantly to the problems of trauma. Such an area unit would not supply enough examples of the rarer orthopaedic problems to enable the peripheral orthopaedic surgeon to become expert in their handling. Certain types of work, such as the long-term care of the crippled child and of surgical tuberculosis, were already, in effect, regionalized by State action. Some of the more specialized orthopaedic problems must be directed either

to university centers or to county orthopaedic hospitals. The link between central and peripheral orthopaedic departments must be preserved through the association of the staffs of one with the other.

Epidemic of Poliomyelitis

Professor H. J. Seddon of Oxford, in describing an epidemic of poliomyelitis in Mauritius, found that the evidence strongly suggested the transmission of the disease through personal contact. He described the conditions of this colony, with its mixed population, and its difficult social and economic state. Later he outlined a scheme for the advancement of orthopaedics in the Colonies, where great opportunities exist for young orthopaedic surgeons. The appointment of such men would be part of a scheme that related them to orthopaedic establishments at home, through which, after three years or so, their future security would be assured.

Splint Construction

Mr. Norman Capener of Exeter demonstrated two splints, which he thought embodied a new principle in splint construction. They were based upon existing types used for the substitution, or support, of deficient muscle activity, as in the familiar toe-raising spring for paralytic equinus. Such appliances usually had springs attached to a rigid framework, whereas the present appliances were themselves constructed into "lively" springs. The appliance for drop-foot, in which the upright element (either single or double) was suitably tempered and coiled at the level of the ankle joint, had the advantage of permitting some lateral mobility in the foot. The second splint, used in ulnar intrinsic paralysis, was based upon an original design, produced by Mr. A. M. Hendry and his co-workers at Derwen, Oswestry, and possessed great advantages of "liveliness" over previous ulnar splints, which rigidly maintained flexion of the knuckle joints.

Arthrography of the Knee Joint

Squadron Leader E. Somerville, Royal Air Force, demonstrated an improved technique for the diagnosis of lesions of the knee joint by air arthrography. A series of 331 knees had been investigated and a very high degree of accuracy in diagnosis had been achieved. Success depended upon attention to the following details: The joint was examined under anaesthesia and filtered air was injected until it was full; the intra-articular pressure was then temporarily increased by bandaging over the suprapatellar pouch; the joint was placed in position over a curved cassette; a sinus cone was used; and radiation was directed accurately in seven tangential planes.

The Fractured Femur

Three different methods of treating simple extra-articular fractures of the femur were discussed.

Mr. R. G. Pulvertaft of Grimsby dealt with fractures of the trochanteric region, for which he preferred the Hamilton Russell method of balanced traction without splintage. The advantages of this method were efficient traction with the joints in the optimal position; complete comfort and muscular relaxation; the maintenance of muscular condition and knee-joint movement; and reduction of chest and decubitus complications, owing to the freedom of the patient to sit up and change position. Careful supervision was essential. This method had given a high proportion of favorable results.

Major John Charnley of the Royal Army Medical Corps, in discussing the treatment of fractures of the femoral shaft by fixed skeletal traction, stressed the importance of controlling lateral angulation and of maintaining immobilization of the fracture, and therefore of the knee joint, for fully eight weeks. A special apparatus, which he had devised, was used in conjunction with the Thomas splint; it was especially designed to give precision, and to be relatively foolproof after accurate adjustment by the surgeon. The essentials were traction upon a pin through the upper end of the tibia, pulling along a line posterior to the femoral axis, with the femur supported across an especially shaped, padded metal fulcrum. Lateral control was achieved by pads screwed to adjustable attachments to the lateral bars. Early movement of the knee was inadvisable and unnecessary.

Mr. G. R. Fisk adopted a completely opposite course for fractures of the femoral shaft. He established early movement by the use of skeletal traction in a flexing splint; this was made from a Thomas splint, sawed off at the knee level and joined by an articulation of the Pearson type.

Mr. V. H. Ellis, in a study of 420 recent fractures of the femoral shaft, supported the advocates of early movement of the knee. The causes of limited flexion were intra-articular adhesions, fixation of the quadriceps, scarring in the region of the fascia lata, especially in high compound fractures, and transfixion of the muscle by spicules of bone.

Actinomycosis

Mr. C. H. Cullen of Winwick reported on five cases of actinomycotic infection of gunshot wounds, in four of which the organism was of an unusual aerobic type. All of the cases were chronic and resistant to treatment. Adequate surgical measures, combined with penicillin, seemed to be of most use. It was interesting that penicillin was beneficial in cases in which concomitant organisms were insensitive to penicillin.

Pollicization of the Index Finger

Mr. E. W. Bintcliffe demonstrated two patients whom he had successfully treated, in conjunction with Major Kilikian, United States Army Medical Corps, by pollicization of the index finger after amputation of the thumb. In such cases, the web space between the index finger and the middle fingers was deepened by dissection. The second metacarpal was divided, allowing the index finger to be abducted, and was attached by wire sutures either to the remains of the first metacarpal or to the trapezium. The defect created between the new thumb and the middle finger was filled by a skin graft. It was desirable to carry out abduction by traction, with a wire transfixing the index finger. The two patients shown had very good function in the "thumbs" thus produced.

Clinical Photography

Mr. P. G. Hennell stressed the importance of color reproduction in clinical photography as an aid to scientific recording and medical education. He believed that in five years black-and-white photography would largely have been superseded by color in the production of scientific records. The apparatus which he had used in clinical photography was demonstrated, as well as a wide selection of color photographs of surgical procedures.

At the meeting on October 26, the following Associate Members were elected:

A. Anderson Bonar, F.R.C.S.E., Ashington, Northumberland.
Miss R. E. M. Bowden, M.B., B.S., London, W.C.1.
Hedley W. Hall, F.R.C.S., Winchmore Hill, N. 21.
Capt. T. P. N. Jenkins, R.A.M.C., Surbiton, Surrey.
Capt. I. N. McIver, R.A.M.C., Colchester.
Lt. Col. C. M. Marsden, R.A.M.C., Millbank, London, S.W.1.
D. A. Richmond, F.R.C.S., Ulverston, Lancashire.
Squad. Ldr. D. P. Rowe, R.A.F., c/o Bank of New South Wales, London, W.1.
A. F. Rushforth, F.R.C.S., Watford, Hertfordshire.
Squad. Ldr. J. J. Williams, R.A.F., Northallerton, Yorkshire.

WAR REPRINT SERVICE OF THE JOSIAH MACY, JR. FOUNDATION

Doctor Rappleye, President of the Foundation, announces that more than 5,000,000 copies of over 400 leading medical and scientific articles have been published by the Foundation's War Reprint Service during the last three years for medical officers of the Armed Forces of the United States and, in so far as possible, Canada, England, New Zealand, Australia, the Union of Socialist Soviet Republics, and China. Doctor Rappleye said that, with the plans for demobilization of the Armed Forces, the Reprint Service will be discontinued by January first.

The Reprint Service of the Foundation has been an effort to bring new and important developments in the science and practice of medicine to medical officers who were largely cut off from the sources of medical information during the war. In the selection of these articles, the Foundation has had the active cooperation of the Committee on Pathology of the National Research Council and of the National Committee for Mental Hygiene. The articles selected for reprint and distribution were those dealing with the most recent scientific developments which had a direct bearing on medical and health problems related to military service. The distribution to the medical officers was worked out in cooperation with the Surgeons General of the Army and Navy and the Air Surgeon. Through the courtesy of the National Committee for Mental Hygiene, more than 1,000,000 reprints were delivered to medical officers of neuropsychiatric units.

In addition to the articles reproduced from journals, the Foundation has published for the Air Surgeon five original monographs, prepared by medical officers of the Army Air Forces, dealing with personality disturbances occurring in combat zones. Over 95,000 copies of these monographs were distributed by the Reprint Service as official documents of the Office of the Air Surgeon. Eight additional monographs and nine reviews of medical literature on subjects of military interest have been prepared and 70,000 copies distributed.

Since August 1944, a News Letter for the Rheumatic Fever and Streptococcus Control Program of the Army Air Forces has been published monthly for the Air Surgeon, and over 1,000 copies each month have been mailed to interested medical officers, military hospitals, and medical-school libraries.

Through the cooperation of the Interdepartmental Committee on Cultural and Scientific Cooperation of the Department of State, 60,000 reprints have been distributed to medical teachers and investigators in forty-eight foreign countries. The Office of War Information requested permission to circulate the Foundation's reprints among more than thirty foreign Outposts, and has reduplicated selected articles for distribution to medical leaders abroad.

The Foundation has expended over $225,000.00 in financing the War Reprint Service.

Surgeons announcing their return to civilian practice from service in the Armed Forces include the following:

Edgar M. Bick, M.D., 1112 Park Avenue, New York 28, N. Y.
John J. Donaldson, M.D., 121 University Place, Pittsburgh, Pennsylvania.
Claude B. Smith, M.D., 603 Atlas Building, Charleston 1, West Virginia.

ACKNOWLEDGMENTS

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Anais Paulistas de Medicina e Cirurgia (São Paulo, Brasil), **50**: Nos. 1 e 2, 1945.
Analecta Medica (Mexico), **6**: Nos. 1 y 2, 1945.
Boletím do Sanatório São Lucas (São Paulo, Brasil), **7**: Nos. 1 e 2, 1945.
Boletín del Colegio Médico de la Habana (Cuba), **8**: Núms. 8, 9, 10, y 11, 1945.
Boletines de la Sociedad de Cirugía de Rosario (Argentina), **12**: Nos. 2 y 4, 1945.
Brasil Médico-Cirúrgico (Rio de Janeiro), **7**: Nos. 2 e 3, 1945.
The Bulletin of the U. S. Army Medical Department (Carlisle Barracks, Pennsylvania), **4**: Nos. 4 and 5, 1945.
Child Development Abstracts and Bibliography (Washington, D. C.), **19**: Nos. 3 and 4, 1945.
Cleveland Clinic Quarterly (Ohio), **12**: No. 4, 1945.
Department of Public Health, City and County of San Francisco (California), Venereal Disease Information, 1945: "An Experiment in the Psychiatric Treatment of Promiscuous Girls" by E. G. Lion, H. M. Jambor, H. G. Corrigan, and K. P. Bradway.
Médica (Matanzas, Cuba), **4**: Núms. 4 y 5, 1945.
The National Foundation for Infantile Paralysis (New York, N. Y.), National Foundation News, **4**: Nos. 11 and 12, 1945.
Radiography and Clinical Photography (Rochester, New York), **21**: No. 2, 1945.
Sanidad y Beneficencia Municipal (Habana, Cuba), **5**: Núm. 1, 1945.
Sociedad de Cirugía de Córdoba (Argentina), **5**: Nos. 6, 7, 8, y 9, 1944; **6**: Nos. 1, 2, 3, y 4, 1945.
United States Public Health Service (Washington, D. C.), Public Health Bulletin No. 293: "The Toxicity of Molybdenum" by L. T. Fairhall, R. C. Dunn, N. E. Sharpless, and E. A. Pritchard; Public Health Reports, **60**: Nos. 40 to 47, 49, and 50; Supplement No. 186; The Journal of Venereal Disease Information, **26**: Nos. 10 and 11, 1945.

Current Literature

THE INTERVERTEBRAL DISC. WITH SPECIAL REFERENCE TO RUPTURE OF THE ANNULUS FIBROSUS WITH HERNIATION OF THE NUCLEUS PULPOSUS. F. Keith Bradford, M.D., and R. Glenn Spurling, M.D. Ed. 2. Springfield, Illinois, Charles C. Thomas, 1945. $4.00.

Less than a dozen years ago, there was added to the list of common causes of low-back pain and sciatic pain the clinical entity of a ruptured intervertebral disc. It soon became evident that disc lesions accounted for many of these cases. So important is this problem in clinical practice that the literature on the subject has become extremely voluminous. It is difficult—perhaps impossible—for the general practitioner and surgeon to read and assess the value of the flood of articles about disc lesions. The profession therefore welcomed the first edition of Bradford and Spurling's small volume. It has saved innumerable hours of reading, and offers in one compact volume, well illustrated, practically all of the present knowledge concerning the intervertebral disc.

The second edition of this volume brings this information up to date. There is very little to criticize, and much to praise. The reviewer feels that the authors might well have laid more emphasis on the value of combined removal of the ruptured intervertebral disc and spinal fusion, as the present trend is toward stabilizing the spine by means of fusion at the time the laminectomy is done. This volume should be on the book shelf of everyone treating patients with low-back pain and sciatic pain.

ATLAS OF SURGICAL APPROACHES TO BONES AND JOINTS. Toufick Nicola, M.D., F.A.C.S. Foreword by Norman T. Kirk, The Surgeon General, United States Army. New York, The Macmillan Company, 1945. $5.00.

The principle of visual education is applied to orthopaedic surgery in an atlas which should prove of value alike to the student and to the practising surgeon. Drawings made from his own anatomical dissections have been produced by Nicola to illustrate clearly each step in the various surgical approaches to the bones and joints, beginning with the skin incision and proceeding in anatomical sequence. The illustrations are accompanied by a brief description of the course to be followed and some of the pitfalls to be avoided, but the text does not include a discussion of surgical techniques, because the author believes each surgeon will develop his own.

The clarity and conciseness of this work make it useful as a reference book, as well as a working guide.

PEDIATRIC X-RAY DIAGNOSIS. A Textbook for Students and Practitioners of Pediatrics, Surgery and Radiology. John Caffey, A.B., M.D. Chicago, The Year Book Publishers, Inc. 1945. $12.50.

During the past thirty-five years, no textbook of diagnostic roentgenology in infants and children has appeared in the English language. The need has been acute, as it is often all too obvious that the training of the average roentgenologist in roentgenographic diagnosis in children has been insufficient, and his interpretations are, therefore, faulty. Many pediatricians and surgeons have attempted roentgenographic diagnosis with an insufficiently broad background, and for them a book, written by a roentgenologist, can present a considerable accumulation of useful knowledge in this field.

All phases of disease in early life are dealt with, and, from the vast experience of the Babies' Hospital in New York, Caffey is able to present much that is new and not readily available. This material proves interesting, and the illustrations and drawings are excellent. One regrets that certain aspects of disease appear incomplete or superficial, and that some conditions are not even mentioned, but probably the subject had become too large for complete treatment in a single volume.

The book is divided into six sections: the head and neck, the thorax, the abdomen and gastro-intestinal tract, the pelvis and genito-urinary tract, the extremities, and the vertebral column. Each section is headed by an excellent discussion of the normal and developmental anatomy. Many of the normal variants and nearly all diseases peculiar to early life are lucidly described and beautifully illustrated. The bibliography is adequate, although incomplete. The chapters on the spine and extremities are particularly good and should be of considerable interest to orthopaedic surgeons.

To all who have occasion to examine the roentgenograms of infants and children, the book should be of inestimable value, not only because there is no other text available in English, but because Caffey presents a book replete with useful information in a style that makes the reading of his text extraordinarily profitable and a real pleasure.

AMPUTATION PROSTHESIS. ANATOMIC AND PHYSIOLOGIC CONSIDERATIONS, WITH PRINCIPLES OF ALIGNMENT AND FITTING DESIGNED FOR THE SURGEON AND LIMB MANUFACTURER. Atha Thomas, M.D., F.A.C.S., and Chester C. Haddan. Philadelphia, J. B. Lippincott Company, 1945. $8.00.

This book is a practical guide in the problems of extremity prosthesis. The selection of the site of amputation and the accredited technique of the present day in the creation of the stump, its aftercare

and conditioning, are correlated with the proper fitting and alignment of the prosthesis. The materials, mechanisms, sockets, and suspension apparatus are clearly and authoritatively presented from the practical standpoint

The chapter on alignment and fitting is especially well done, and fills a long-felt need. It should be of great benefit to all concerned. Indeed, the entire book is well done The upper-extremity prosthesis is fully discussed, and the shortcomings are presented in a straightforward and stimulating manner The chapter on prostheses for children adequately covers a neglected field and adds to the merit and value of the book.

This 289-page volume is the result of the collaboration of two authorities on the subject, one a well-known orthopaedic surgeon, the other an experienced limbmaker Both are thoroughgoing students of their respective fields. The book is a valuable addition to the orthopaedic library.

General and Plastic Surgery, with Emphasis on War Injuries J. Eastman Sheehan, M.D New York and London, Paul B Hoeber, Inc. (Medical Book Department of Harper Brothers), 1945 $6 75.

This book was written by a well-known plastic surgeon, who has published several treatises on plastic surgery and has seen a good deal of war surgery in Spain and Britain He has endeavored to show the application of the principles of plastic surgery to general surgery, but most of the book is devoted to general surgery with particular reference to battle injuries Sheehan has borrowed many of his facts and many illustrations from Bailey, who has published a great deal on traumatic surgery The author gives credit to many plastic surgeons, both at home and abroad, for helpful suggestions in preparing the book, which is written with the hope that lessons learned from the War may be applied to peacetime surgery.

The first chapter deals with general considerations, including the types of missiles found in various types of fighting, the types of wounds made by such missiles, the need for prompt treatment, methods used to combat shock and pain, and the indications and techniques for plasma transfusions

Subsequent chapters take up wound excisions, gas gangrene, control of infections blast injuries at sea and on land, and the treatment of burns The chapter on wounds and burns of the hand and foot is excellent, and deals with the anatomical as well as the surgical aspects Wounds of the various regions are considered in order, and the basic plastic procedures are described The illustrations are excellent

This is an unusual book and of great value

The Osseous System A Handbook of Roentgen Diagnosis Vincent W Archer, M D Chicago, The Year Book Publishers, Inc, 1945. $5.50

Archer has prepared a concise handbook on the roentgenographic diagnosis of the osseous system, which he dedicates to the occasional roentgenologist. It contains an excellent choice of reproduced roentgenograms, representative of bone abnormalities, varying from congenital anomalies and fractures to bone tumors and metabolic disorders The contents are so arranged as to afford quick reference

Two points are stressed throughout First, commonplace errors in the interpretation of shadows are demonstrated so that these pitfalls can be avoided, and, second, the differential diagnoses are given consideration so that alternate possibilities will not be overlooked This handbook will give assurance to the interpretations of the occasional roentgenologist, and at the same time clearly indicate the zone in which more expert opinion is necessary. It is better suited to a place beside the viewing box in the office or hospital than in the index files of a large library

The Extremities Daniel P. Quiring, Ph.D, Beatrice A Boyle, Erna L Boroush, M A, and Bernardine Lufkin, A.B. Philadelphia, Lea & Febiger, 1945 $2 75

Although entitled "The Extremities", this small book is devoted entirely to a delineation of the muscles of the upper and lower extremities,—their origins, insertions, actions, blood supply, and nerve supply.

At first glance the drawings seem "flat", but careful examination shows that they have accomplished their purpose in showing clearly and accurately the individual muscles depicted

A page is devoted to each muscle The diagrammatic sketch of the muscle is shown, followed by concise statements as to origin, insertion, and function of the muscle, as well as the nerve and artery which supply it Included also are references to Gray's Anatomy and to Cunningham's Text-Book of Anatomy.

Since all the drawings are based on original dissections, the little book represents a tremendous amount of work It will be a valuable handbook for medical students and physiotherapists, as well as a reference book for physicians

Physical Chemistry of Cells and Tissues. Rudolf Höber (with the collaboration of David I. Hitchcock, J. B. Bateman, David R. Goddard, and Wallace O. Fenn). Philadelphia and Toronto, The Blakiston Company, 1945. $9.00.

The subject matter of this book is physiology as a branch of physiochemical science, dealing with life as a physical, although exceedingly complex, system that may be subjected to scientific analysis, as any natural object.

The book is divided into sections, beginning with the fundamentals of classical physical chemistry and cell physiology. The permeability of the cell membrane to organic non-electrolytes and to electrolytes, to weak bases and weak acids, and to dyestuffs, is considered. The present status of our knowledge of the plasma membrane is discussed and reviewed. The influence of some extracellular factors on cellular activity is considered. An attempt is made to present the general pattern of cellular respiration. Physical chemistry furnishes the theoretical basis for understanding the apparent complexity of cell respiration, and for supplying tools to probe within the living cell and to separate and study the individual enzymes. One section is devoted to the study of contractile tissues. The last, and a very important section, deals with intestinal absorption, urine formation, elaboration of digestive juices, and the permeability of the body surface of animals and plants.

This book does not claim to offer universal information in the field of the physical chemistry of cells and tissues, but it is of great value as a guide to the biologist, the chemist, the physicist, the physiologist, and the physician by bringing together, in concrete form, the fundamental laws of science upon which human physiology is built. With its diagrams, formulae, and fundamental laws, it will meet a real need as a reference book.

Fractures and Orthopaedic Surgery for Nurses and Masseuses. Arthur Naylor, Ch.M., M.B., M.Sc. F.R.C.S.(Eng.), F.R.C.S.(Edin.). Foreword by Ernest Finch, M.D., M.S.(Lond.), F.R.C.S.(Eng.) Baltimore, The Williams and Wilkins Company, 1945. $5.00.

This book, as stated in the preface, was written for the purpose of showing the nurse how the principles of general surgery are applied in orthopaedic surgery; it is apparently designed to help nurses and masseuses understand and follow the principles of orthopaedic surgery. It is an interesting book, well written and illustrated, and contains some very clever diagrams. The descriptions are good. As its title suggests, it covers fractures and general orthopaedic subjects. No detailed surgical technique is described and there is no bibliography, although the procedures of other surgeons are occasionally mentioned in the text.

Although it is an excellent book for nurses in terms of orthopaedic surgery and fractures, it gives no nursing technique. For medical students, it would supplement the larger orthopaedic texts. It is, of course, written from a British point of view, so some of the procedures may not be quite familiar to the American reader. Most of the apparatus depicted is good, but Naylor still advocates certain forms of apparatus, such as the old Thomas hip splint and hip frame, which are no longer in general use in the United States. The principles of treatment are sound, and there is an excellent index.

Acute Injuries of the Head. Their Diagnosis, Treatment, Complications and Sequels. G. F. Rowbotham, B.Sc., F.R.C.S. Foreword by Norman M. Dott, M.B., Ch.B., F.R.C.S. Ed. 2. Baltimore, The Williams and Wilkins Company, 1945. $8.50.

The appearance of a second, enlarged edition of Rowbotham's book, the only modern British treatise on head injuries, was to be expected in view of the special circumstances which prescribed its original content.

The first edition of 277 pages appeared in 1942. It was prepared to meet a critical need, arising out of the exigencies of the British national emergency. Global war had placed the responsibility of managing acute head injuries in the hands of many who were without special training in neurosurgery. There was no authoritative British treatise to which they could turn for guidance until Rowbotham's monograph appeared. It was, quite understandably, concerned with war injuries to the exclusion of certain peacetime problems. Revision with enlargement of scope was necessary, if the book was to become a standard work on its subject, as predicted by British reviewers.

The author's qualifications for an undertaking of this nature are ample. He is the senior pupil of Professor Jefferson, the dean of British neurosurgeons, who has long been preoccupied with the problems arising out of head injuries. The author has so ordered his affairs that his own clinical experience in this field is now considerable. He is, in addition, a student and investigator of his subject, with a faculty for clear exposition.

The second edition of this book, replete with superb original illustrations, attempts to compress within 414 pages an account of the mechanisms, pathology, diagnosis, treatment (operative and non-operative), sequelae, and rehabilitation of practically every known type of head injury.

Although the book is an admirable piece of work, it would have profited by the author's calling

more freely upon the experience of others in places where his own experience appears to be slight. Thus, in the discussion of the subdural hematomata of infancy, no mention is made of the diagnostic and therapeutic usefulness of subdural taps. Equally important omissions occur in the presentation of carotid-cavernous sinus fistulae. At these and a few other points, deficiencies are not covered by appropriate references.

Parts of the book suffer from an avoidable lack of perspective. Thus in a twenty-four-page account of epilepsy, medical treatment is afforded a single paragraph, in which the clinical toxicology of the anticonvulsive agents and measures for the control of status receive no mention. Similarly, the subject of chemotherapy and of antibiotic therapy is alloted but two pages, wherein space is found for historical data on penicillin but not for the clinically important matters of intrathecal administration and the choice of agents for direct application to cerebral tissue.

Because of the author's attempt to cover so much ground in so few pages, the book cannot be recommended in its entirety to any one audience. The rather large sections devoted to operative technique will be helpful to neurosurgical house officers, but lost on practitioners, and incomplete for specialists. On the other hand, the chapters dealing with mechanisms, pathology, and rehabilitation recommend themselves highly to student, house officer, practitioner, and specialist. The book certainly belongs in the libraries of medical schools and hospitals.

PHYSICAL TREATMENT BY MOVEMENT, MANIPULATION AND MASSAGE. James B. Mennell, M.A., M.D., B.C.(Cantab.). Ed. 5. Philadelphia, The Blakiston Company, 1945. $7.00.

This book maintains a unique position among texts on physical therapy as a very personal book. The signal skill and understanding of the author, acquired from years of experience in treating patients with physical methods, are divulged in detail. Unlike many American textbooks, which consist largely of a compilation of the literature on the subject, in this book one finds but brief reference to the writings of others. Nowhere else, in fact, can one find the information contained in this volume. The technique of massage, manipulation, and exercise is described in explicit detail, often with considerable repetition when essentially the same methods are used for different disease conditions. The physiological effects and the rationale of treatment are based largely on *a priori* reasoning, from apparent good results. This is unavoidable to a large extent, because of lack of scientific research in the field. One feels the considerable enthusiasm of the writer in ascribing value to the methods described, but at the same time warnings of possible lack of usefulness and even contra-indications to treatment are included.

As is to be expected, the discussion largely centers on those orthopaedic conditions for which massage and exercise are outstandingly advisable. Heat, electricity, and other physical agents are only briefly mentioned.

More detail of technique of physical methods is included than will interest the average orthopaedic surgeon or physician. On the other hand, to properly prescribe and instruct the physical therapist in the care of patients, considerable knowledge of this subject is essential. The surgeon who will take the time to read this book and to learn the possibilities of physical treatment will acquire practical information, which should lead to more intelligent use of physical therapy, and better results from it. This book is practically essential for student physical therapists in England, and is worthy of study by all.

A TEXTBOOK OF SURGERY. By American authors. Edited by Frederick Christopher, B.S., M.D., F.A.C.S. Ed. 4. Philadelphia and London, W. B. Saunders Company, 1945. $10.

The roster of contributors to this volume includes many surgeons who are recognized as authorities in special phases of surgery. An unusual number of changes in this list have been necessary since the previous edition. The constant improvement in techniques and methods means that such a book must have frequent revisions, if it is to be kept up to date. Since the previous issue, so many developments have come in this field that whole new chapters were necessary in this edition, as, for example, the chapter on chemotherapy in surgical infections.

Excellent illustrations, adapted from many sources, help in the understanding of the text.

Since 1936, when this work first appeared, it has been recognized as a valuable reference book. This fourth edition makes more secure its position as a text of unusual merit.

FRACTURES OF THE JAWS. Robert H. Ivy, M.D., D.D.S., F.A.C.S., and Lawrence Curtis, A.B., M.D., D.D.S., F.A.C.S. Ed. 3. Philadelphia, Lea and Febiger, 1945. $4.50.

The third edition of Ivy and Curtis's book contains some additional material not included in the former editions. Stout's loop method of intermaxillary wiring has been added. A description is given of Risdon's method of constructing an arch bar with wires attached to two posterior teeth. When ligated to the teeth it gives a very firm fixation, with a close approximation to the form of the dental arch.

Skeletal fixation is described, and is recommended for fractures of the mandible in order to control fragments in which teeth are absent or do not afford adequate attachment for intra-oral appliances. For maxillary fractures, Adam's method of fixation by internal wiring has been included, in addition to the conventional procedures formerly described.

Condylar fractures are given only the most cursory consideration; fracture-dislocations are not mentioned at all. Both types of fracture are relatively common, and are best diagnosed with the aid of roentgenograms taken in an anteroposterior direction. This method is used routinely in most hospitals today, but is not described in the chapter dealing with roentgenographic technique, written by Ennis.

The methods advocated by the authors may be employed without the use of highly technical dental laboratory procedures; such procedures often consume considerable time and include the taking of impressions and the fitting of wax models, which may be very uncomfortable or even painful.

FACIAL AND BODY PROSTHESIS. Carl Dame Clarke, Ph.D. St. Louis, The C. V. Mosby Company, 1945. $5.00.

This is virtually a handbook of materials and methods used in the making of prostheses. The author obviously is familiar with the historical background, and has kept himself abreast of the modern developments in this field. His approach in this volume is more from the standpoint of a technician and artist than from that of a clinician, although for the most part his statements are medically sound.

Materials and techniques are discussed in some detail, with the exception of those which have been fully described before; these he refers to in an excellent bibliography. He describes in greatest detail the use of latex; but the passages on the use of wax, plaster-of-Paris, and agar compositions are adequate. The discussion on the coloring and the application of prostheses is quite good.

The chapter on the use of resilient and elastic resins is too brief, and the small place devoted to ᵃʳd prosthetic devices is hardly justified. The chapter on the repair of cranial defects by cast chip-bone ᶠts is probably out of place in this volume, for it applies to a very limited field, which has more to do with the grafting of living substances than with the subject of prosthetics. One case is shown where a prosthetic nose and upper lip is used; this procedure is usually unwise, for the upper lip never looks completely normal. However, as a temporary expedient before plastic surgery is finished, such a device may be justified.

In spite of these relatively minor objections, this book may be recommended highly because of the clarity with which it is written, because of the excellent discussion of materials and methods, and because of its lack of superfluous words. It certainly should be most useful to reconstructive surgeons, medical artists, and dentists.

A TEXTBOOK OF SURGERY. John Homans, M.D. Ed. 6. Springfield, Illinois, Charles C. Thomas, 1945. $8.00.

The new edition of Homans's Surgery is a textbook of even greater value than the previous edition. It reflects the lessons of the war years, when special surgical problems have confirmed the value of many procedures and shown others to be futile. The frequent recognition of conditions, previously considered rare, has emphasized the necessity of understanding these entities. The occurrence among Army personnel of certain fractures and other injuries, seldom seen in civilian life, has provided an opportunity for evaluation of the various methods of treatment.

In this edition, as in each previous revision, the aim of the author has been to discard the outworn material and to include the accepted newer methods of diagnosis and treatment. This constant effort to keep the volume up to date explains, in part, the place which the book holds as a text for the student and a reference of value to the surgeon. The carefully prepared illustrations, as well as the bibliographic index, add greatly to the usefulness of the book.

OSTEOTOMAIS EM GERAL, SUA FREQÜÊNCIA E SUA IMPORTÂNCIA EM ORTOPEDIA (Osteotomy in General, Its Frequency and Its Importance in Orthopaedics). Dagmar Aderaldo Chaves. Rio de Janeiro, A Casa do Livro Ltda., 1943.

Chaves traces the history of osteotomies since 1815, and reviews the various indications for osteotomy. He divides osteotomies into subcutaneous and fully open, and classifies the open osteotomies as linear, complex, cuneiform, and curvilinear. The techniques of special osteotomies, such as derotation, and shortening or lengthening of a limb, are discussed. The book is well illustrated with line drawings. The case histories of nine patients who had recently undergone osteotomies are reported. Although nothing new is brought forward, the book contains a wealth of information about this special surgical procedure.

PLASTER OF PARIS TECHNIQUE IN THE TREATMENT OF FRACTURES AND OTHER INJURIES T B Quigley, Lieutenant Colonel, M C New York, The Macmillan Company, 1945 $3.50

The author has taken a subject which ordinarily has been taught by the apprentice method, and has put the teaching into words This book points out the fundamentals indications, and dangers in the use of plaster for the fixation of extremities and trunk injuries In the matter of detailed techniques, it is dogmatic to the exclusion of alternate methods As a reference book in the technique of plaster application, it is certainly a thorough, single set of rules, which should give to the surgeon who becomes familiar with it more confidence and quicker agility in mastering the art

THE MEDICAL ANNUAL A YEAR BOOK OF TREATMENT AND PRACTITIONER'S INDEX Editors Sir Henry Tidy, K B E, M A, M D, F R C P, and A Rendle Short, M D, B.S, B Sc, F R C S Bristol, England, John Wright and Sons, Limited, 1945

The Medical Annual for 1945 is the sixty-third consecutive volume to be published in England It is a yearbook of treatment and the practitioner's index The many and varied conditions are presented by contributors who are recognized British authorities, each in his own field Conditions in which new advances have been made during the year are especially discussed The subject matter is amply illustrated by forty-seven plates and many drawings

This volume, like its predecessors, will prove of value as a quick and handy reference book for the general practitioner, not only in the British Isles, but in America as well Here the latest information on medicine and surgery are available in concise form Considering the severe wartime restrictions which must have been encountered, the publishers of the Medical Annual for 1945 are to be congratulated upon producing a volume equal to the standard of Annuals of previous years

STRUCTURE AND FUNCTION OF THE HUMAN BODY Ralph N Baillif, Ph.D, and Donald L Kimmel, Ph D Philadelphia, J B Lippincott Company, 1945 $3 00

One of the authors is Assistant Professor of Anatomy at the Louisiana State University School of Medicine and the other, Associate Professor of Anatomy at Temple University School of Medicine They have prepared this book to meet what they feel is a real need in this branch of teaching—a simple text for an introductory course in anatomy and physiology

The Introductory Survey which they call "Unit One" surveys the fields to be considered,—Protoplasm and Cells, Physical Organization in the Animal Body, and Organ Systems of the Body This Unit comprises nearly a third of the book, and is intended as a background for the student to help him in understanding the physical building materials and the correlation of their structure and functions, as well as the individual organ systems and the relation of each to the body as a functioning mechanism

The other three Units take up the eight organ systems

Unit Two Skeletal, Muscular, and Circulatory Systems,
Unit Three Digestive and Respiratory Systems,
Unit Four Urogenital, Endocrine, and Nervous Systems

A Glossary and a good Index add to the value of the book

Undoubtedly the book is well adapted for the group for whom it was written It is not for the advanced medical student, it is not for the physician or surgeon, but will be valuable for his secretary, it is an interesting book for the perusal of the lay person who wishes to understand better the structure and function of the human body

A TRÍPLICE ARTRODESE NA ESTABILIZAÇÃO DO PÉ PARALÍTICO (Triple Arthrodesis in the Stabilization of the Paralytic Foot) Dagmar Aderaldo Chaves Rio de Janeiro A Casa do Livro Ltda 1943

Chaves reviews the normal and pathological anatomy of the posterior tarsal and ankle joints, the muscular control, and the usual deformities with paralyses The various types of stabilization of the foot and ankle joint are illustrated and described Six cases of arthrodesis, performed at the Hospital Jesus, are reviewed No new opinions are brought forward nor new procedures described A full review of the literature is given

RESULTATE DER OSTEOSYNTHESIS COLLIS FEMORIS A M SV JOHANSSON (Results of Osteosynthesis of the Neck of the Femur by the Method of Sven Johansson) Arne Birch-Jensen *Acta Chirurgica Scandinavica,* 87 432, 1942

Out of sixty-three cases of fracture of the neck of the femur treated by closed reduction and nailing with Sven Johansson's modification of the Smith-Petersen nail, forty-eight were still alive for an end-result study Forty-three were personally examined by the writer Roentgenograms are submitted of the technical failures in eight cases A statistical analysis is offered, with comparative analyses from

the literature. There was an immediate mortality of 4.8 per cent. The complication of necrosis of the femoral head occurred in ten cases; in seven, it appeared more than twelve months after the operation. There was definite bony healing in 54 per cent., pseudarthrosis and necrosis of the femoral head in 7.9 per cent., necrosis of the femoral head in 4.8 per cent., necrosis of the femoral head and osteo-arthritis in 3.2 per cent., and osteo-arthritis in 4.8 per cent. In 25.4 per cent. of cases there was no roentgenographic examination later than twelve months after the osteosynthesis. The functional results were good in 44 per cent., fairly good in 12.7 per cent., and poor in 27 per cent. In 15.9 per cent. the period of observation was less than twelve months.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Arthrodesis in Osteo-Arthritis of the Hip and Septic Coxitis Sequelae. Anders Karlén. *Acta Chirurgica Scandinavica,* 89: 309, 1943.

In forty-seven cases of degenerative arthrosis and twelve cases of ancient septic arthritis of the hip, the end results following arthrodesing operations were studied. Various forms of arthrodesis were used. In the cases of degenerative arthrosis, there were only thirty-six with bony union, four with fibrous ankylosis, and six with no consolidation. Of these, the three cases with simple nailing all resulted in bony union. The combined juxta-intra-articular arthrodeses gave fifteen bony ankyloses, one fibrous ankylosis, and two complete failures. The partial intra-articular and juxta-articular arthrodeses gave twelve bony ankyloses, two fibrous ankyloses, and one complete failure. The intra-articular arthrodeses resulted in five bony ankyloses, one fibrous ankylosis, one failure, and one postoperative death. The juxta-articular arthrodeses in three cases gave one bony ankylosis and two failures.

Functionally the results were good in forty-five of the forty-six living patients. In one, a second operation prevented return to work. In two cases, the results were considered functionally good, although the patient failed to return to work for other than physical reasons.

In the twelve cases of ancient septic arthritis, bony fusion was obtained in ten patients. In one, there was failure of consolidation. There was one death. The eleven living patients all resumed their work.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Fractures of the Head and Neck of the Radius. Erik Feltström. *Acta Chirurgica Scandinavica,* 92: 349, 1945.

An end-result study in ninety-nine cases of fracture of the radial head and neck includes eighty-nine treated conservatively and ten upon which an operation was performed. The results were good, except in five of the cases treated conservatively. One was a nine-year-old boy with an unreduced displacement of the radial head and limitation of elbow motion. The other four cases were in adults who should have had operative treatment.

On the basis of the end-result study, the writer suggests the following treatment:

1. Non-dislocated fractures should be treated conservatively.
2. Large, dislocated fragments should be excised.
3. In comminuted fractures, the head should be resected.
4. Dislocated fractures of the neck should be reduced, if necessary by open operation. If this fails, in adults resection should be performed.
5. In children, displaced fractures of the neck of the radius should be reduced by closed or by open methods. Unreduced displacement of the head causes considerable limitation of function. Resection should never be performed because of the resulting growth disturbance.
6. Immobilization should be for as short a period as possible. Active motion should be started within from two to four weeks. Massage is not indicated. The application of heat is of benefit.

—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Deeply Situated Multiple Glomus Tumors. Ragnar Frykholm. *Acta Chirurgica Scandinavica,* 92: 368, 1945.

A case is reported in which a glomus tumor, the size of a hazel nut, was removed from the fascial space between the interosseous membrane and the muscles of the calf, 10 centimeters proximal to the ankle joint. This was a case in which Bergstrand had previously reported the presence of multiple glomus tumors. According to the writer, there were only three previous reports in the literature of deep-seated glomus tumors, the remainder being superficial. He cites nine references to reports of superficial, multiple glomus tumors.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Abnormality of the Calcaneus as a Cause of Painful Heel. Its Diagnosis and Operative Treatment. A Fowler and J. F. Philip. *The British Journal of Surgery,* 32: 494–498, 1945.

The writers have noted that in a certain group of patients with painful heel, a definite bursa external to the tendo achillis can be excised with complete relief. In another group with the same symptoms

no definite bursa could be found, but the skin and subcutaneous tissues showed chronic inflammation. These patients were not benefited by operation. However, roentgenographic studies showed that these patients had an abnormality in the bone consisting of a smooth, regular, prow-like projection immediately beneath the tendon at the point of disability.

This finding led to an investigation into the variations of the os calcis. Interesting illustrations of these variations are shown.

An operation has been devised to remove this excess bone. A curved incision is employed and a flap dissected downward. The tendon is cut through by an inverted "Y" incision and the projecting bone is smoothed off. The tendo achillis is sutured and the wound is closed. The foot is put up in plaster in plantar flexion for three weeks. Disability ends in six weeks. The operative results are said to be good.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

DELAYED PARAPLEGIA FOLLOWING FRACTURES OF THE VERTEBRAE. Lambert Rogers. *The British Journal of Surgery*, 32: 514–517, 1945.

Paraplegia complicating a vertebral fracture is usually produced at once by the nipping of the cord between two vertebrae. Rarely, the onset of paraplegia is delayed, so that there is an interval between the time of injury and its appearance. During this interval conduction in the cord is unimpaired, its functions are normally discharged, and it would appear to have escaped damage. Symptoms of a spinal-cord lesion then appear; the numbness and paralysis may be either transient or lasting.

The article includes detailed reports of four illustrative cases. In all four paraplegia occurred after an interval in which there were no cord symptoms. In two cases the paraplegia lasted only a few days. In the others it was persistent, and operation was required to relieve it.

The paraplegia was due to bony compression of the cord, which probably was the result of movement of the bony fragments subsequent to the initial fracture.

INTERNAL DERANGEMENTS OF THE KNEE IN MILITARY PRACTICE. Hewson I. J. Kellam. *The Canadian Medical Association Journal*, 53: 143–147, 1945.

The author served with the Canadian Orthopaedic Unit in Great Britain. Of a very large number of soldiers with symptoms referable to the knee, 400 cases are reviewed, in which meniscectomy was performed by various surgeons of the Unit. He makes the following observations:

Lesions of the medial meniscus are more frequent than those of the lateral meniscus.

Tears in the peripheral part of the cartilage heal more readily than those in the inner two thirds or free border, because of the vascularity of the peripheral part.

Recurrent attacks of internal derangement may occur after trivial injuries; many of them were received during skiing, football, or other athletic activities.

Careful differential diagnosis is essential to rule out, as the cause of the disability, such conditions as arthritis, tabes dorsalis, Pellegrini-Stieda disease, fracture of the anterior spine of the tibia, and injuries to the cruciate ligaments.

After a diagnosis of torn meniscus with recurrent replacement has been established, meniscectomy should not be too long delayed. The best time to operate is from twenty-five to twenty-six weeks after the first injury.

The author prefers a small anteromedial incision of either the Jones or Fisher type. When necessary, a second incision to remove the back of the cartilage is made over the posterior horn. In most cases the whole of the cartilage should be removed; when the tear is large and of the bucket-handle type, only the torn portion should be removed.

Quadriceps-setting exercises are started before operation and are resumed forty-eight hours after operation. In 250 cases the knee was immobilized in extension for three weeks; in 150, no splint was used and movement within the compression bandage was allowed. There seemed to be no difference in the results from the two methods.

Of the group of 400, 73 per cent. of those rated as A-1 upon admission to the hospital were still in this category six months to one year after discharge from the hospital.

THE USE OF PLASTICS IN PLASTER CASTS. Arthur M. Vineberg, F. G. Rice, and E. C. Brown. *The Canadian Medical Association Journal*, 53: 170–171, 1945.

The authors have done considerable research on materials which would be suitable for casts, and yet not have the disadvantages of plaster-of-Paris. As a result of their experiments, they recommend a mixture of water-soluble plastics and plaster-of-Paris. Casts made from this mixture have been found to be 50 per cent. stronger and 10 per cent. lighter than those made from ordinary plaster. The results of the use of plastics in plaster casts are promising.

LIPOCONDRODISHOFIA (Lipochondrodystrophy). L. Expósito y A. de Feréa. *Cirugía Ortopédica y Traumatología*, **12**: 51, 1945.

The case histories of two patients suffering from lipochondrodystrophy are presented. A brother of ten and a sister of eight were brought to the Children's Clinic of the Mercedes Hospital, Havana, because of abnormality in walking. Both children showed deformities of the hands with fixed flexion of the fingers, a mild kyphos, genu varum, corneal opacity, and slight enlargement of the cranium. Laboratory studies revealed nothing significant. Roentgenograms showed osseous deformity, a flattening of the anterior part of the vertebral bodies, and flattening of the articular surfaces. No other member of the family showed evidence of the disease. The outcome in these two patients is not given.

The disease is rare, familial, and probably congenital. Lipoid substances are usually found in various tissues, particularly in the cerebrum. Theories of etiology are reviewed, and the pertinent literature is cited. Seven autopsies are recorded in the literature. The findings are somewhat similar to those of Niemann-Pick disease. Foam cells are often lacking and lipids may be deposited in granular form. The epiphyses show a small amount and an irregular arrangement of proliferating cartilage. Shortness of stature is the rule.—*John G. Kuhns, M.D., Boston, Massachusetts.*

SPINAL CARIES SIMULATING PSEUDOHYPERTROPHIC MUSCULAR DYSTROPHY. P. N. Laha. *Journal of the Indian Medical Association*, **14**: 227–228, 1945.

Laha reports an unusual case of spinal caries of the eleventh and twelfth thoracic vertebrae, which so closely simulated pseudohypertrophic muscular dystrophy that at first the latter diagnosis was made. The simulation was evidently due to compression paraplegia, in which the muscular weakness was such as to mimic muscular dystrophy. The correct diagnosis was established by roentgenogram. The author does not state whether there was any localized tenderness or rigidity in the region of the lower thoracic spine.—*Robert M. Green, M.D., Boston, Massachusetts.*

NEUROSURGICAL ASPECTS OF LUMBAR AND SCIATIC PAIN. Edgar F. Fincher. *Journal of Medical Association of Georgia*, **34**: 149–154, 1945.

Fincher deals chiefly with cartilage damage, spinal cord tumors, and neuroses. A careful chronological history is of first importance. All cartilage ruptures are due to trauma, even if the frank displacement was precipitated by violent sneezing. One may get a history of trauma in tumors of the spinal cord, but this is merely coincidental. The patients with compensation neuroses all give a history of trauma.

The character of the back pain in patients with cartilage damage is important. The pain is exaggerated on motion and intensified by coughing or sneezing, and is alleviated by complete rest. In intradural tumors the onset of pain is insidious and slow in development; it is primarily radiating, and back pain may be absent. The pain is consistently exaggerated by rest. Patients get out of bed and walk for relief. In the psychological cases the patient strives to impress the doctor with the intensity of his suffering. The back pain is diffuse in location; the extremity pain is likely to involve the entire limb, and does not follow a nerve distribution. It is always exaggerated by work and not helped by rest.

Pain due to other causes is discussed. Important signs in cartilage cases are a flattening of the lumbar curve, and a sciatic list away from the painful extremity. There is muscle splinting on the painful side. The pelvis may tilt, and patients often limp. Calf atrophy can often be determined by measuring. In cord tumors, nothing is noted on inspection in most cases. In compensation cases bizarre positions may be assumed.

The differential diagnosis is discussed. Roentgenograms are necessary; stereoscopic anteroposterior films and lateral films are made. In disc cases the films show (1) straightening of the lumbar curve, (2) narrowing of the intervertebral space, and (3) "sciatic list". Opaque injections to visualize the spinal canal are not necessary in cartilage cases, but are of value in tumor cases. They are severely condemned in psychological cases, and surgery is to be avoided in these cases.

There is much good common sense in this article, and many practical points in differential diagnosis.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

SCIATIC PAIN: ITS RELATION TO PAIN IN THE BACK AND SPINAL DEFORMITY. E. N. Wardle. *The Medical Press and Circular*, **1**: 197–201, 1945.

The author states that, of 120 consecutive cases in which the patient complained of pain in the leg, eighty-one were found to have neuralgia only, and thirty-nine, a true neuritis. Many patients with true sciatic neuralgia will admit having had attacks of intermittent back pain. Examination reveals rigidity of the lumbar spine, and painful limitation of movement in all directions. Twenty-nine cases of this type of osteo-arthritis were treated by simple immobilization of the spine in a plaster jacket for approximately four weeks. There was one failure.

Eighty cases of sciatic scoliosis, which was characterized by severe pain, list of the whole body to one side, strong spasm of one erector spina, and wasting of the whole quadriceps muscle, were treated by the application of a head-suspension plaster jacket. There were eleven failures. In some cases, laminectomy and removal of a herniated disc were indicated, and six operations were done. Four patients returned to work, one had good recovery after removal of a meningioma, and one died.

Treatment of thirty-seven cases of sciatic pain associated with congenital lumbar abnormalities was successful in twenty cases, unsuccessful in seventeen. Fifteen cases of injury to the erector spinae and lumbar aponeurosis were helped by injection of two or three cubic centimeters of a 1 per cent. novocaine solution into the painful area, and by manipulation.

YAWS. C. F. Chenoy. *The Medical Press and Circular,* 1: 60–62, 1945.

The author has made extensive studies of yaws among jungle tribes in India. It occurs in infants, babies, children, and in young and old men and women. The cause of infection has been proved to be direct contact with primary or secondary ulcers by the broken skin. Laboratory findings among all insect vectors examined by the author were negative. He demonstrated the *Spirochaeta pertenue* in almost 100 per cent. of intact yaws lesions, in 40 per cent. of ulcerated lesions, but rarely in old lesions. Kahn's test was positive in all cases.

Three stages of the disease are described. In the primary stage, a single raised granular sore appears, after an incubation period of from two to three weeks. This lesion may heal before the onset of the secondary stage, or it may persist, or it may break down to form a persisting ulcer with granulating base and raised edges. In the secondary stage, the typical lesion is a desquamating rash over face, limbs, trunk, and buttocks. Joint pains and synovitis of the knee and elbow joints are followed by swellings of the long bones, especially the legs. The soles and palms may have fissures and cracks, and condylomata may appear. This stage can last for months or years. In the tertiary stage, the lesions are saber tibia, gummata, gangosa, secondary ulceration giving rise to deep sores with cicatricial contractions, and infection of bones with crippling and disfigurement. The mortality is small. Death is slow and is usually due to starvation after years of pain and disfigurement.

Mass treatment in the field included salvarsan or its derivatives. In primary cases, one injection, in 153 cases, resulted in 136 complete clinical cures, seventeen partial cures; two injections in 101 cases brought ninety-nine complete cures, two partial; and three injections, in forty-eight cases, forty-eight complete cures. In secondary cases, one injection, in 1793 cases, gave 1436 complete cures, 357 partial cures; two injections, in 1280 cases, resulted in 1152 complete cures, 128 partial; and three injections, in 594 cases, 569 complete cures, and twenty-five partial cures. In tertiary cases, one injection, in 3784 cases, resulted in 2834 complete cures, 950 partial cures; two injections, in 2595 cases, brought 2205 complete cures, 390 partial cures; and three injections, in 1012 cases, 912 complete cures, 100 partial cures. Relapses were seen on the way back through the villages treated,—in 30 per cent. of patients receiving one injection, in over 20 per cent. of patients who had had two injections, and in 10 to 15 per cent. in cases receiving three injections.

MANDIBULAR FRACTURES AT KING COUNTY HOSPITAL, TREATED BY ROGER ANDERSON SKELETAL FIXATION. J. Wayne Graham. *Northwest Medicine,* 44: 250–252, 1945.

Twenty-six cases of mandibular fracture are reviewed. Approximately half were compound fractures, but in only three osteomyelitis developed. Two of these were cases of open reduction, and in the other case a tooth was allowed to remain in the line of fracture. Interdental wiring was done where feasible, but in edentulous cases the Roger Anderson skeletal-pin fixation was used.

The anatomical structures must be carefully studied, and two pins inserted into each fragment, halfway between the lower mandibular border and the alveolar canal. The external maxillary artery and the mental foramen are to be carefully avoided. Intranasal ether vapor is the best anaesthesia.—

Charles Lyle Hawk, M.D., Los Angeles, California.

SOBRE EL TRATAMIENTO DE LAS FRACTURAS RECIENTES DEL CUELLO DE FÉMUR (Treatment of Recent Fractures of the Femoral Neck). J. Troncoso Rozas. *Revista Española de Cirugía, Traumatología y Ortopedia,* 2: 213, 1945.

Rozas reviews the progress made in the treatment of fractures of the femoral neck since Sir Astley Cooper divided them into extracapsular and intracapsular fractures. The methods of treatment which he considers are: (1) simple supine rest in bed; (2) continuous traction; (3) immobilization in a large spica (Whitman-Löfberg); (4) early surgical intervention; and (5) continuous extension followed by osteosynthesis at the opportune time. (The latter is the method of election.) Rest in bed, preferably with the femur in abduction, is reserved for fractures in aged individuals with cardiorenal complications, particularly intertrochanteric fractures.

With continuous extension, there is a tendency for irritation of the skin to develop, and external rotation of the femur is common. This method is reserved as a postoperative measure. Traction with a Kirschner wire is more effective than adhesive plaster. The spica of Whitman-Löfberg gives good results in about 50 per cent. of patients under sixty years of age. In regard to immediate operative treatment, ideal conditions are rarely present, and the general condition of the patient is most important. For these reasons there should usually be a period of preparation for the osteosynthesis. In preparation, local anaesthetic at the site of the fracture, and skeletal traction in 30 degrees of abduction, should be used until reduction is obtained. The author prefers this to the method of Leadbetter, and feels that all fractures of the femoral neck, both intracapsular and extracapsular, should be treated by osteosynthesis, with the exception of those few cases in which impaction or interlocking of the fragments prevents movement. In addition, those cases described by Pauwels and Böhler, in which the plane of the fracture is greater than 25 degrees, may be treated conservatively. Contra-indications to osteosynthesis are infancy, fascial hemorrhage, phlebitis, pressure sores, or local infections.

Rozas gives the following end results: Of fifty-eight patients treated conservatively which he was able to follow, twenty showed consolidation with a good anatomical reduction, five showed a moderate coxa vara, twelve had fibrous union, ten had pseudarthroses, and eleven died during treatment. Seventeen patients between the ages of thirty-seven and eighty-two were treated by osteosynthesis and followed from one to ten years. Thirteen were treated by a triflanged nail with excellent results in ten, coxa vara in one, and pseudarthroses in two. Of two treated with cork screw, one obtained a perfect result and one had coxa vara. One patient was treated with Moore pins with a perfect result. (The author does not mention the treatment in the remaining patient treated surgically.)

The author feels that if the fracture is well reduced, the fixation material is non-oxidizable and non-electrolytic, and the osteosynthesis is well performed with good impaction, the results will be uniformly good.—*John G. Kuhns, M.D., Boston, Massachusetts.*

Dificultades en el Diagnóstico precoz de la Tuberculosis Osteoarticular (Difficulties in the Early Diagnosis of Osteoarticular Tuberculosis). Sara Satanowsky. *La Revista de Medicina y Ciencias Afines,* **7**: 445–450, 1945.

The very early diagnosis of tuberculosis of the bones and joints is discussed in detail in this good article. Early diagnosis is difficult and sometimes impossible, as the signs and symptoms are often indistinguishable from those found in arthritis. The early diagnosis is most important, since failure to recognize and treat the disease may have dangerous sequelae; while treating an individual for tuberculosis when he does not have it may cause permanent joint stiffness, as well as a social disturbance to the patient and his family. Johanson has stated that 61 per cent. of patients with osseous tuberculosis have pulmonary involvement; Petter's figure is 85 per cent. Two forms of osteo-articular tuberculosis are found pathologically,—the granular and the caseous.

The roentgenographic examination is of great value in late cases, but in very early cases there are only two suggestive findings: osteoporosis and an alteration (almost always a decrease) in the roentgenographic density of the joint itself. The tuberculin reaction is only occasionally of help. A positive test is of no value, because most people have old pulmonary lesions; a negative test may be a false negative, although this is uncommon. A marked local flare-up of the involved joint is a very suggestive diagnostic sign. The sedimentation rate and blood count are of little or no value. Examination of the joint fluid is most helpful. The presence of tubercle bacilli is diagnostic, but they can seldom be found on direct smear. A positive guinea-pig inoculation is diagnostic. Intraperitoneal inoculation is time-consuming; intraganglion inoculation is better, because a shorter time is required. The organisms can frequently be cultured from the joint fluid in a special medium of Hohn (glycerine and egg) in from eleven to sixteen days. A biopsy of the involved joint is often diagnostic and is frequently indicated.—
Major Louis W. Breck, M.C., Camp Swift, Texas.

L'enclouage médullaire des fractures des os longs. Méthode de Kuntscher (Kuntscher's Method of Medullary Nailing of Fractures of Long Bones). G. Laurence. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur,* **30**: 32, 1944.

Kuntscher reported in 1939 and also in 1940 on the technique and preliminary results of his medullary nailing of fractures.

The advantages are as follows:

1. Solid fixation of the fracture with early mobilization of the limb.
2. Osteosynthesis with opening of the fracture site.
3. Creation of biological and mechanical conditions most favorable for speedy formation of callus with a minimum of apparatus.

To overcome the disadvantage of using voluminous metal for fixation, which acts as a foreign body, the rod was triflanged or biflanged, and was made of special steel called V2A.

Experimentally, the method proved satisfactory. Many successful clinical results were reported.

Rigid rods were used for the femur and the ulna; flexible rods which could be made rigid, once introduced into the bone, were used for other bones. The introduction of the rod could be done under roentgenographic control.

For satisfactory fixation, the distal fragment has been engaged for at least five centimeters. If closed reduction is impossible, the fracture site has to be exposed.

The patient is permitted out of bed in from eight days to three weeks after the introduction of the rod. The rod may be removed after consolidation, in from twelve to eighteen months.

The method may be used in any age group, for a variety of fractures, including pathological fractures, and also in pseudarthrosis.

Apparently a number of complications were observed by surgeons, but the opposition, which was strong when the method was introduced, has subsided with subsequent reports.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

ÉVOLUTION A LONGUE ÉCHÉANCE DE L'OSTÉOCHONDRITE DE LA HANCHE. INFLUENCE DU TRAITEMENT SUR LA QUALITÉ DU RÉSULTAT (Late Evolution of Osteochondritis of the Hip. Influence of Treatment on the Results). L. Tavernier et J. Mallah. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur,* 30: 65, 1944.

The authors analyzed the late results in a group of twenty-five patients, examined from nine to twenty-five years after the onset of osteochondritis. The present article includes only a roentgenographic study of the development of the affliction.

Several cases were observed in the very early stages. At the onset of pain in the hip, no changes were observed by roentgenogram. Only after several weeks was a widening of the epiphyseal plate observed. Subsequently the typical picture of osteochondritis appeared.

The authors describe two types of deformity: The well-known mushroom type starts with a widening of the epiphyseal plate, followed by reduction in size and condensation of the epiphyseal nucleus, and finally by a modification of the neck; this was observed in eighteen patients. The angulated type, in which the head becomes triangular in shape, was seen only five times, and differs so much from the mushroom type that it could be taken for a different entity, were it not for the intermediary roentgenograms.

In two cases there was complete restitution of the femoral heads with early mushrooming. These patients were subjected to strict immobilization for one and two years, respectively.

Functionally, these two patients with complete restitution of the heads were normal. Of the eighteen patients with mushroomed heads, two had a perfect functional result.

A second group of nine patients with good function was observed, seven of whom had a mushroom deformity and two an angular deformity of the head. These patients had no pain or limp, and only slight limitation of motion.

A third group of nine patients with only satisfactory results also included seven with the mushroom deformity and two with the angular deformity.

Of the twenty-five patients, three were severely disabled. Two of them showed a mushroom deformity and one an angular deformity. The roentgenograms showed advanced arthritis.

The authors believe that roentgenographic evidence of deformity is compatible with good function. In 50 per cent. of good results, only 8 per cent. showed complete roentgenographic restitution. Twelve per cent. had unsatisfactory function, with severe arthritis. The authors believe that prolonged immobilization may produce anatomical and functional restitution, while abortive treatment leads to a severe deformity and arthritis in 12 per cent. of the patients.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

TRAITEMENT PAR LES INFILTRATIONS SYMPATHIQUES DES TROUBLES RÉFLEXES POSTTRAUMATIQUES, DITS PHYSIOPATHIQUES (Treatment of the Posttraumatic Reflex Disturbances Known as the Physiopathic Syndrome). G. Arnulf. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur,* 30: 161, 1944.

The author describes a method of treatment of the troublesome posttraumatic disturbances observed after injuries to the extremities, characterized by atrophy, vasomotor changes, oedema, changes in the appearance of the skin and nails, and osteoporosis.

Citing the infiltration of the sympathetic ganglia originated by other surgeons, the author recommends the following procedure:

1. The stellate or the lumbar ganglia must be infiltrated, according to the involvement of the upper or lower extremity.
2. Large doses of novocaine (twenty cubic centimeters) must be used for injections.
3. The infiltration must be repeated ten or fifteen times every three days in the beginning, and once a week thereafter.

4. Immediately after the injection, when vasodilatation is obtained, the involved extremity must be "worked" by light passive motions, followed by active use of the wrist and fingers.

5. It is useful to infiltrate locally the wrist or fingers for increased mobilization of stiffened joints.

The patient's interest should be evoked in the comprehension of the treatment, and in appreciation that each infiltration is only a step in the general improvement.

The number of infiltrations may be lessened by early treatment. The author cites a case in which one infiltration was sufficient to produce recovery.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

CARPAL BONE INJURIES. John D. Sherrill. *Southern Medical Journal,* **38**: 306-312, 1945.

Sherrill reviews injuries to the small bones of the wrist. Fresh fractures of the carpal scaphoid are treated by prolonged immobilization in a plaster cast to the wrist, including the thumb; the wrist is in radical deviation and 30 degrees of dorsal flexion. At least four months should pass before a diagnosis of non-union is made. Cases diagnosed as late as three or four weeks after injury should be treated as fresh fractures. In the treatment of non-union, the following methods have been advocated: immobilization, drilling, bone-grafting, excision of one or more fragments or of the entire bone, and fusion of the wrist joint. Several cases of persistent non-union have been seen, which have had few disabling symptoms. Cases should be carefully studied before surgery is decided upon.

In dislocation of the semilunar, an attempt at closed reduction under anaesthesia should be made. If not successful, open operation is done and the bone is replaced or excised. Other fractures and dislocations of the carpal bones are discussed.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

COLLES' FRACTURE. J. Warren White. *Southern Medical Journal,* **38**: 415-417, 1945.

In cases of Colles's fracture, the author advocates complete reduction under a general anaesthetic, check by roentgenogram, and maintenance of the hand and wrist in pronation and ulnar deviation (Cotton and Loder position) in a plaster cast from metatarsal heads to mid-humerus. After two or three weeks the position of the hand may be changed, and the cast shortened. Splints, either home-made or custom-made, are not so satisfactory as plaster casts. The plaster should not be removed for five or six weeks.

The conclusions are as follows: (1) Do not attempt reduction without roentgenograms. (2) Use a general anaesthetic. (3) Secure anatomical reduction. (4) Use plaster casts, but not splints. (5) Do not remove the cast too soon. (6) Have the patient move the fingers. (7) Do not use physiotherapy too strenuously. (8) Do not resort to subsequent surgery in older people.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

THE USE OF SKIN FLAPS IN THE REPAIR OF SCARRED OR ULCERATIVE DEFECTS OVER BONE AND TENDONS. Earl C. Padgett and John H. Gaskins. *Surgery,* **18**: 287-298, 1945.

The authors report a series of ninety-seven patients treated for deep adherent scars, many of them over bones or tendons, by means of thick skin flaps. In many instances, the entire operation was carried out in one procedure, thereby reducing the period of hospitalization to approximately one-fifth that required in procedures making use of delayed or tube flaps.—*Edward L. Compere, M.D., Chicago, Illinois.*

HUMAN FIBRIN FOAM WITH THROMBIN AS A HEMOSTATIC AGENT IN GENERAL SURGERY. EXPERIMENTAL STUDIES AND CLINICAL USE. Orville T. Bailey, Franc D. Ingraham, Orvar Swenson, John J. Lowrey, and Edgar A. Bering, Jr. *Surgery,* **18**: 347-369, 1945.

Fibrin foam, a material obtained in the fractionation of human blood plasma for the preparation of human fibrinogen and thrombin, is an effective absorbable hemostatic agent when soaked in human thrombin solution. This material will control bleeding from oozing surfaces, from the dural sinuses, and even from large cerebral veins.

The authors emphasize, however, that the use of fibrin foam with thrombin should not replace the careful control of bleeding by means of meticulous dissection and adequate placing of sutures.—*Edward L. Compere, M.D., Chicago, Illinois.*

PULMONARY EMBOLISM IN FRACTURES OF THE HIP. Harry Golodner, Louis J. Morse, and Alfred Angrist. *Surgery,* **18**: 418-423, 1945.

Heart disease and bronchopneumonia have been thought to be the most common causes of death, following fractures of the hip. Pulmonary embolism has not been considered as often as this article would indicate that it should be. Of 304 patients who were treated for intertrochanteric or intracapsular fractures of the neck of the femur, there were eighty-six deaths. Twenty-five autopsies were performed, and the causes of death in these patients were as follows: pulmonary embolism in nine, bron-

chopneumonia in seven, arteriosclerotic heart disease in four, and miscellaneous causes of death, including sepsis in five

This study would indicate that pulmonary embolism from venous thrombosis in the veins of the lower extremities is the most frequent cause of death in cases of fracture of the hip From their observations, the authors conclude also that this complication is less frequent in patients who become ambulatory early. They have suggested prophylactic bilateral ligation of the superficial femoral vein, combined with lumbar sympathetic block, for the prevention of pulmonary embolism in fractures of the hip of patients who cannot be made ambulatory early —*Edward L Compere, M D, Chicago, Illinois*

The Treatment of Progressive Bacterial Synergistic Gangrene with Penicillin. Frank L Meleney, Sidney T Friedman, and Harold D Harvey *Surgery,* 18 423–435, 1945

Treatment of three cases of progressive bacterial gangrene, one of the chest wall, a second of the abdominal wall, and the third of multiple lesions involving areas of both legs and the chest, was reported The organisms found in the cultures were of numerous bacterial species In the first two patients, the spread of the gangrenous infection was checked by penicillin Response to this therapy in the third patient was very slight Surgical excision was attempted but the patient died on the morning of the seventh postoperative day from a large pulmonary embolism

The authors conclude that the presence of *Escherichia coli* and *Pseudomonas pyocyanea* in the infected gangrenous areas of Case No 3 were responsible for the failure of penicillin in the treatment of this patient They demonstrated in the laboratory that these organisms elaborated penicillinase, which completely inactivated penicillin *in vitro* They conclude, however, that penicillin should be tried in all patients with bacterial progressive gangrene —*Edward L Compere, M D, Chicago, Illinois*

Three Hundred Fifty-Two Cases of Tetanus Roald T Vinnard *Surgery,* 18 482–492, 1945

In most areas within the United States, tetanus has become an extremely rare disease A report of 352 patients treated in the Charity Hospital of Louisiana at New Orleans in a single ten-year period represents a series which is large enough to constitute a scientific study The total mortality was 45 per cent Vinnard urges routine immunization by tetanus toxoid of the entire population, routine administration of prophylactic antiserum in the treatment of all injuries of patients who have not previously received toxoid immunization, and education of the lay public to report, and of doctors to recognize and institute immediate therapy for, symptoms of early tetanus

The above recommendations are for the purpose of preventing tetanus The program of treatment, where tetanus has already appeared, was also discussed Perhaps it would be well to add that early and complete débridement and cleansing of all wounds for the removal of dirt and other foreign material would be an additional safeguard against tetanus, as well as against other infecting organisms —*Edward L Compere, M D, Chicago, Illinois*

Gunshot Fractures of the Shaft of the Humerus William T Fitts, Jr, Charles K Kirby, and Ernest A Bray *Surgery,* 18 493–497, 1945

Gunshot fractures of the shaft of the humerus comprised approximately 3 per cent of all battle casualties among the patients who were admitted to the general hospital from which this study was made The hanging arm cast was used in treating the majority of these fractures, and bone union was accomplished in almost every instance in which there was no significant bone loss Ninety-three per cent of the wounds were débrided in forward hospitals Débridement was performed within the first twelve hours in 69 per cent of all the injured Sulfanilamide was used locally in every wound, and oral sulfonamides were given to all patients before admission to the hospital

Most of the patients arrived at the hospital wearing abduction plaster spica casts In the majority, there was marked disalignment of the fractures, which corrected immediately after the spica was removed and the arm was permitted to drop to the side in a hanging cast Associated nerve injuries occurred in many of these fractures and were the most frequent cause of permanent disability —*Edward L Compere M D Chicago Illinois*

Studies in Experimental Vascular Surgery Sidney Smith *Surgery,* 18 627–643 1945

A very complete review of the literature including a history of vascular surgery, is included in this report Using dogs for experimentation, numerous techniques previously described were repeated under controlled conditions The use of a soluble rod inserted into the cut ends of an artery was found to be a very readily applicable method of approximating accurately the edges of arteries while they were being sutured This rod went into solution in the pulsating blood in one minute or less The arterial sheath was then sutured securely all the way around the artery at the site of the anastomosis —*Edward L Compere, M D, Chicago, Illinois*

ORTHOPAEDIC SURGERY FOLLOWING PERIPHERAL-NERVE INJURIES. V. D. Chaklin. *Voprosi Neurokhirurgyi*, No. 3, 50, 1944.

There are areas of nerve injuries, where all attempts at repair will be useless. There are other areas in which nerve suture gives mediocre results after long convalescence.

In the upper extremity, in the presence of grave injuries to the brachial plexus, the treatment consists in: (1) operative correction through an osteotomized clavicle with special attempt to repair the median nerve; (2) support of the extremity with a hinge joint for the elbow; (3) arthrodesis of the shoulder after a period of eight to ten months, followed by immobilization for three months; (4) muscle transplantation for extension, if flexion of the wrist and fingers has been restored. In the presence of total paralysis of all the muscles of the upper extremity, arthrodesis of the shoulder and the elbow with a tenodesis of the wrist is advisable. Radial-nerve paralysis may require either transplantation of tendons or a combined suture of the nerve with transplantation of tendons. For median-nerve paralysis involving the thenar muscles, one of Bunnell's procedures is recommended.

In the lower extremity, injuries to the femoral nerve involving the quadriceps present difficult problems. Contractures of the knee joint have to be overcome and then transplantation of the biceps performed; or combined transplantations of the tensor fasciae latae and sartorius may be advisable. Among the less desirable corrective measures are arthrodesis and arthroereisis of the knee joint.

Injuries to the sciatic nerve require prolonged physiotherapy, the wearing of light braces, and tenodesis of the extensor tendons or posterior arthroereisis of the ankle. Special attention should be given to the often overlooked contracture of the toes.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

CAMPTOCORMIA. A FUNCTIONAL CONDITION OF THE BACK IN NEUROTIC SOLDIERS. S. A. Sandler. *War Medicine*, 8: 36, 1945.

No doubt very few of our orthopaedic colleagues are familiar with the term "camptocormia". The author defines this as a "hysterical phenomenon seen during wartime in certain neurotically ill soldiers". The condition is manifested by pain in the lumbar area and by a marked flexion of the trunk. It may or may not be precipitated by trauma. Primarily it is functional in origin.

Sandler presents a long series of case reports on soldiers, some of whom have had attacks prior to entering the Army. These patients are never erect, but when standing or walking bend forward at an angle of from 60 to 90 degrees. Most of them had either adored or hated their fathers; thus the father-son complex was developed to a rather extreme degree. The fathers of many also had complained of pain in the back throughout the span of memory of the patient.

A few of the patients were cured by psychotherapy. Strangely, in almost every case the back-bending phenomenon was attended, or had been preceded, by sexual impotence. Sandler expresses the opinion that many of these patients were at least potential homosexuals.

Whether in military or civilian life, these patients are usually incorrectly diagnosed and considered to be malingerers. The orthopaedic surgeon who sees such a patient should try to obtain a neuropsychiatric history and, when the correct diagnosis has been made, refer the patient to a psychiatrist if possible.—*Edward L. Compere, M.D., Chicago, Illinois.*

MADURA FOOT. F. E. Clough. *The Western Journal of Surgery, Obstetrics and Gynecology*, 53: 153, 1945.

Madura foot is usually considered a rare tropical disease indigenous to India, but forty-three cases have been reported in the United States and Canada and four unpublished cases, originating in California, were discussed in 1944. This term includes "all fungoid diseases of the feet in which there is grain formation, regardless of fungous etiology". There are at least forty-eight species of fungi that might cause the disease, and many of these belong to the family of *Actinomyces*. All species give rise to the same symptoms, pathological changes, and end results. They all produce grains or seeds of various colors as their distinguishing features.

A case is reported of a forty-three-year-old Mexican agricultural worker who was first seen in 1930, because of discomfort in his left foot. In 1934 he was given corrective foot pads. Roentgenograms at that time showed no bone changes. In 1936 the foot began to swell and roentgenograms showed several tiny drill holes through the fourth metatarsal. Several small sores had broken open and healed. On March 8, 1940, the entire foot was greatly swollen. The skin was thick and darkened. Nodules, varying in size from a small shot to a marble, could be felt everywhere. Sinuses were excreting a thin, yellowish pus from which could be expressed tiny brownish seeds. Fungi were found in the crushed seed. Pain was not a major complaint. Roentgenograms showed a worm-eaten appearance of all the metatarsals and tarsals; the contour of the bones remained normal, but one metatarsophalangeal joint showed beginning destruction. All types of medication were tried with no benefit. In February 1942 the left foot was amputated. Recovery was uneventful.—*Commander F. Harold Downing, U.S.N.H., Shoemaker, California.*

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PSYCHOSOMATIC PROBLEMS IN MILITARY ORTHOPAEDIC SURGERY *

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World Wars I and II have given impetus to the study and understanding of the neuroses. Involvement of the musculoskeletal system by these disorders is more common in the Army than was formerly appreciated. Orthopaedic surgeons, as well as other clinical specialists, have come to the realization that there is a psychiatric aspect to their specialty which they can neither ignore nor deal with merely by intuition. Many have been so fascinated by the physical phase of the work that too little recognition has been given to psychosomatic problems,—even to the extent of carrying out heroic operative procedures upon neurotic patients.

To diagnose a syndrome as functional merely by methodically ruling out all known organic lesions is to disregard the fact that the psychosomatic entities have characteristics of their own. A psychosomatic diagnosis must be based upon what the patient has, and not alone upon what he has not. Of course, a complete search for organic lesions should not be neglected. We now recognize that, if musculoskeletal symptoms of psychogenic origin are identified, our responsibility to the patient does not always end when we have found that there is no organic lesion.

In discussing the frequency with which psychological problems are encountered in an Orthopaedic Section, Menninger[4] has said: ". . . every medical patient and every surgical patient has a psychological aspect to his illness". In a study of 450 consecutive cases on an Army Medical Service which were given diagnoses of arthritis or of allied organic conditions, Boland and Corr found "psychogenic rheumatism" to be the most frequent cause of disability. There may even be an important psychic factor in fractures and other accidents. Dunbar refers to accident proneness, and presents evidence that a personality factor is responsible for approximately 80 per cent. of accidents, leaving not more than 20 per cent. which are "accidental" accidents. A survey of all patients hospitalized on the Orthopaedic Section during the year 1943 disclosed that 11.1 per cent. had outstanding psychological problems which were either the sole cause, or the most important contributing cause, of their disabilities. Among the patients in the Orthopaedic Out-Patient Department during the same year, over 25 per cent. were predominantly psychogenic.

* Prepared for presentation at the meeting of The American Academy of Orthopaedic Surgeons, January 1945, which was canceled in compliance with the request of the Office of Defense Transportation.

Three types of psychological problems have regularly appeared in the Orthopaedic Section: (1) psychogenic problems in which no relevant organic lesion could be uncovered, either in the present or in the past; (2) psychogenic problems which were secondary to organic lesions; and (3) psychogenic problems which perpetuated some of the physical symptoms of a healed organic lesion. From a psychiatric standpoint, the cases with psychogenic musculoskeletal symptoms may be divided into those with (a) conversion reactions, (b) anxiety or tension states, and (c) elaborations (psychogenic elaboration of symptoms from an organic lesion). Various combinations of these three types are more common than pure types.

Where there are concomitant functional and organic symptoms, every effort is made to determine the relative part each plays in the clinical picture, and therapy is directed toward each component. The need for recognition of the emotional factors associated with organic diseases is well stated by Weiss and English: "The day is near at hand for the final outmoding of the 'either-or' concept (either functional or organic) in diagnosis and to place in its stead the idea of how much of one and how much of the other, that is, how much of the problem is emotional and how much is physical".

More than 1,000 cases, in which the psychogenic factor was either the most important cause or the sole cause of musculoskeletal symptoms, were referred to the Orthopaedic Section. All cases were referred for orthopaedic diagnosis and treatment by physicians in dispensaries and in the various Clinical Sections of this and other Army Hospitals. By referring most cases with disabling musculoskeletal symptoms first to the orthopaedic surgeon, the complex cases which prove to be purely psychological problems may be quickly studied, recognized, shown to have no orthopaedic complications, and promptly transferred to the psychiatrist. This procedure gives the psychiatrist and the patient reassurance that there is no definite evidence of an organic lesion of the musculoskeletal system.

Not nearly all of the cases displaying functional musculoskeletal disability were diagnosed as psychoneuroses. Many were classified by the psychiatrists as cases of simple adult maladjustment; this meant in most instances that the patient had been adjusted emotionally for most of his life, but had now succumbed to overwhelming psychical stresses, usually incident to military service. Most of these patients recovered or improved under psychotherapy and environmental manipulation. Of the fully developed neuroses which were observed, the largest group revealed conversion phenomena in the form of pain, non-anatomical areas of hypalgesia, paralysis, or bizarre posture. An accurate classification by the psychiatrists as to type was frequently impossible, due to the mixture of symptoms. An element of anxiety was uncovered fairly regularly, but pure cases of anxiety neurosis have been in the minority. Neurasthenia, hypochondria, and compulsion neurosis were all observed in the Orthopaedic Section, but these findings were exceptional. No attempt will be made to give a detailed account of the psychiatric aspect of the cases studied, because the writer is not a psychiatrist. Rather, an attempt will be made to present those phases of the problem which are of interest to the physicians who treat musculoskeletal conditions. Surgeons have hesitated to depart from the "solid ground" of the soma to tread on the "thin ice" of the psyche, but there is increasing evidence that the day is approaching when they will freely discuss the psychological aspects of their surgical cases.

PSYCHOLOGICAL HISTORY

Menninger[3] has outlined an excellent abbreviated neuropsychiatric examination which can be conducted in a few minutes. The Adaptability Rating Military Aeronautics of the Army Air Forces Flight Surgeons includes a similar examination. This type of abbreviated history is taken on all cases in the Orthopaedic Section in which the source of symptoms is obscure, or in which inadequate objective and laboratory evidence exists to explain the subjective symptoms. The long, comprehensive history taken by the psychiatrist requires

considerable time and experience; such a study is essential only for the understanding and evaluation of complex cases. An abbreviated psychological history can be taken by any physician in conjunction with the regular clinical history, and in a high percentage of instances it will give sufficient information for an adequate evaluation. After such a study a psychological disorder will not often be perpetuated by being treated as an organic entity, or denied therapy because no organic lesion is identified.

In dealing with soldiers, one of the first questions in a psychological history regards adjustment to military life. Many factors in Army service cause anxiety, and in the emotionally immature individual this growing anxiety can precipitate neurotic physical symptoms. Neurotic symptoms very often develop in soldiers with poor psychical resistance during the first few months of service, before combat conditions are encountered. These soldiers cannot withstand regimentation and steady, hard, monotonous work, in addition to being denied their home life, luxuries, and old friends. Their despair and resentment give rise to frustration and conflicts, which usher in mental depression and disturbed sleep. Sleeplessness and long hours of hard work soon lead to chronic fatigue, increased insomnia, and more anxiety. The soldier may then meet an adverse situation which is "the straw that broke the camel's back" and may dramatically convert his emotional chaos into physical symptoms; if these symptoms are manifest in the musculoskeletal system, he will probably be sent to an Orthopaedic Section. In a psychological history it is important to record a previous nervous breakdown of the patient or of a member of his family. An unhappy, loveless childhood is also given the greatest significance by psychiatrists. Inability to work, to go to school steadily, or to get along well with people usually indicates maladjustment, and such findings are frequent in the neuroses. Excessive fatigue, insomnia, nightmares, nervous tension, globus hystericus, palpitation of the heart, hyperhidrosis, eneuresis, physical and mental depression, vertigo, fainting, numbness and tingling of the extremities, timidity, sexual perversions. sulkiness, laziness, tantrums, and seclusiveness may all be of psychological origin. A history of one or several of these symptoms may indicate the presence of an important emotional problem, and may throw light on the patient's emotional maturity.

SUBJECTIVE FINDINGS

Psychogenic Pain in the Musculoskeletal System

It is enlightening, and most helpful from the standpoint of diagnosis. to persuade the neurotic patient to describe his symptoms accurately. At the outset he usually describes his physical distress merely as a pain, just as does the patient with an organic lesion. There are important shades of difference between organic and psychogenic pain, and these differences may serve as useful clues to the correct interpretation of the entity at hand. It must be emphasized, however, that one is not justified in basing a diagnosis of a functional disorder solely upon any one symptom in the clinical picture, regardless of how significant that symptom may appear.

What the neurotic individual describes as pain in the joints or in other regions may be discovered, upon further questioning, to be a feeling of tension or of pressure. The region may feel tight and the tension may increase steadily when the part is kept in one position. Such tension may be described as a "pulling sensation", and may be associated with throbbing. The focus of psychogenic distress may feel as though a great weight were upon it, and as though the area were intensely fatigued. Peculiar and bizarre postures may be assumed, such as forward flexion of the spine (camptocormia). There is no position of complete relief, and no relief is obtained from immobilization. In a normal-appearing joint, a psychogenic factor should be suspected when a disabling pain is not influenced by motion or rest of the joint. An occasional patient is considerably relieved by bed rest. and appears willing to spend many months in the hospital. When in bed he escapes from part

of his anxiety, and is thereby partially relieved of the physical manifestations of the anxiety.

Bizarre patterns of radiating pain may also characterize a neurosis. One of the most consistently psychogenic pains is that which radiates from the coccyx or sacral region up the spine, to end in the upper back or in the occipital region. Pain radiating from a distal point proximally is far more likely to be of functional origin than pain which radiates distalward.

Reaction to Procaine

A distorted or paradoxical reaction to procaine, injected into a site of musculoskeletal pain, is often a clue to a psychological disorder.

Other Complaints

Other complaints, some of which may occur with purely organic lesions, may be associated with the neuroses. These include sensations of numbness and of "pins and needles" in the extremities, which feel as though the arms and legs are asleep; compelling impulses to change position continually in order to prevent the legs from becoming unbearably tense or "dead"; daily variation in the site or sites of discomfort; the feeling that a part of the body is missing, particularly the extremities; inability to relax a portion of the body; and diffuse weakness of an extremity.

OBJECTIVE FINDINGS

The physical examination may reveal no positive findings, or it may disclose many. The objective findings most frequently observed in association with psychological disorders are: (1) circumferential (non-anatomical) hypalgesia; (2) hysterical paralysis; (3) vasomotor instability; (4) hyperhidrosis; (5) hyperactive reflexes; (6) camptocormia and other psychogenic postures; (7) astasia-abasia (ability to sit and move about in bed, but not to stand or walk); (8) coarse intention tremor of an extremity; (9) anxiety symptoms (apprehension, frustration, bounding pulse, and dilated pupils); and (10) blindness, deafness, aphasia, or aphonia. Again it must be emphasized that a clinical picture is not necessarily considered psychogenic merely because one of the above findings is present. The diagnosis is made after weighing each subjective symptom and objective finding, and analyzing the picture as a whole.

Circumferential Hypalgesia ("Stocking-and-Glove" Anaesthesia)

One of the most significant objective evidences of a neurosis, and one which is frequently overlooked, is the presence of non-anatomical areas of diminished sensation. Such areas are nearly always circumferential, and they involve extremities more frequently than other parts of the body. However, the patterns of distribution appear to be legion. A detailed study was made of 100 consecutive cases in which conversion reactions included circumferential hypalgesia (Figs. 1 to 4). At the bottom of each sketch, below the soldier's rank, initials, and age, is a statement of the major site of the subjective musculoskeletal symptoms. All cases having similar subjective complaints are grouped together. It is at once apparent that the site of musculoskeletal symptoms did not often dictate the pattern of the hypalgesia. Neurotic hypalgesia may be associated with functional subjective symptoms in other body systems, particularly the cardio-respiratory and gastro-intestinal systems, and the patterns of hypalgesia are similar to those observed when the functional symptoms are centered in the musculoskeletal system. Ten of the 100 patients had hysterical paralysis, and in each instance the paralysis was at the site of pain.

Although conversion hysteria seldom produces analgesia and anaesthesia, it frequently is associated with hypalgesia and hypaesthesia. Since the diminished response to the

sensation of pain is relative, the line of demarcation between the site of the patient's normal response and the site of his diminished response must be identified. This can be done only by carrying out an examination which tests every one or two inches of skin, along lines running the length of the entire body. A sharp pointed instrument, such as a pin or needle, is used, and the skin is pricked quickly, sharply, and firmly. An accurate interpretation of abnormal pain sensation can be made only when the examiner knows what constitutes a normal response in the various regions of the body. To have a clearer idea of the normal response, complete sensory examinations were done on 400 individuals with no known physical or mental disorders. There is considerable variation in the normal response, but certain regions are consistently more sensitive to pinprick than others. The more sensitive areas include the palms and the volar aspect of the fingers, the antecubital region, the axilla, eyelids, lips, groins, genitalia, popliteal regions, and the soles of the feet. The medial aspect of the arm is more sensitive than the lateral aspect, the temporal regions are more sensitive than the top of the head, and most of the face is more sensitive than the neck.

During the examination, information can often be gained simply by watching the patient's response, rather than by asking him to state whether the pinprick feels sharp or dull. If there is hypalgesia of a part, the patient will nearly always flinch sharply when normal sensation is encountered at the line of demarcation. If no flinching occurs, the patient is asked whether there is a sudden change in the way he feels the pinpricks. Every effort is made to avoid suggesting a response to the patient. The temptation to mark levels with a skin pencil should be resisted, and to discuss hypalgesia patterns with the neurotic patient serves only to increase his burden of anxiety. It is unusual for the patient himself to discover the hypalgesia.

In many cases the regions of hypalgesia were tested for their response to touch, heat, and cold. In the involved areas there was a consistent diminution in the patient's reaction to all forms of sensory stimuli, but no test is so striking nor so satisfactory for identifying levels of demarcation as that for pain sensation. In areas of neurotic hypalgesia, the diminished pain sensation involves the deep structures to the same degree as it does the skin. This is particularly evident when needles are inserted without pain into the periosteum, the ligaments, and the joint capsules. Compression of these structures is also painless, and this fact is most striking when the tendo achillis or the pretibial periosteum is firmly compressed without producing pain. Compression of the heel cord and pretibial compression can be employed in the lower extremities, in addition to the sensory check. In the upper extremities, finger-tip or carpal compression serves the same purpose.

Numerous patients showing hysterical hypalgesia were examined on several occasions to determine the course of the sensory changes. In a few cases the changes entirely disappeared in from two to ten days, but in most instances the changes lasted several weeks and persisted at least as long as the pain and distress. Several cases that were followed through more than one episode of conversion symptoms disclosed sensory changes during each episode, and were entirely free of such changes between episodes. It was not unusual for the pattern of hypalgesia to change, sometimes radically, but most cases showed a consistent pattern and unchanging levels. In studying the sharpness of the demarcation, it was common to find that as little as one-quarter of an inch separated the zone of hypalgesia from the zone of normal sensation.

The medical literature includes few descriptions of the variations in distribution and the characteristics of hysterical sensory changes, and it is for this reason that the patterns of 100 cases showing these changes are presented. This is a relatively large series to be screened from a non-psychiatric section, but many thousands of cases were studied and treated in the Orthopaedic Section during a period of approximately two years.

Of the 100 patterns, ninety showed multiple sites of hypalgesia and seventy-two had some degree of involvement of all four extremities. Changes were confined to the right

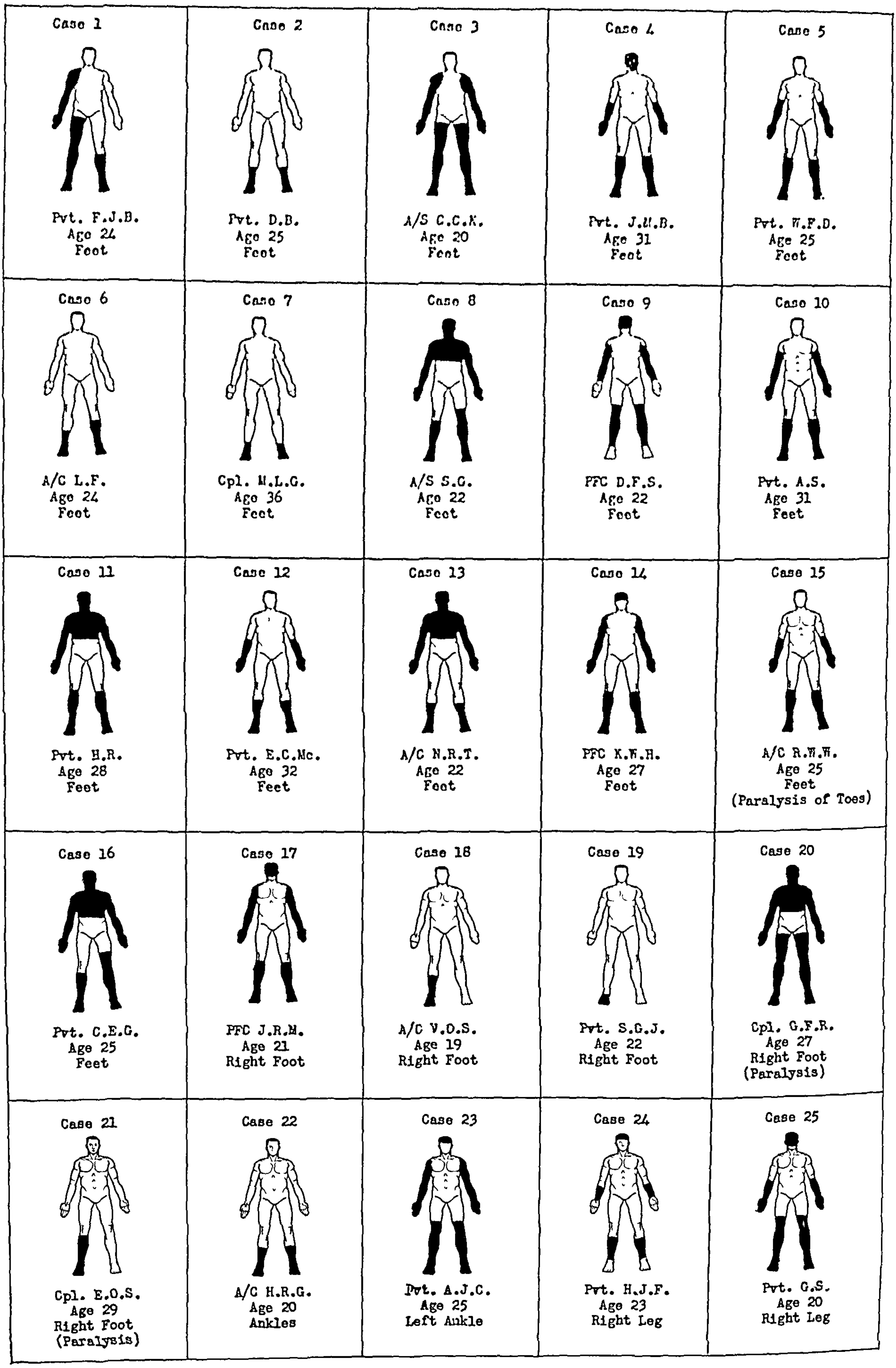

FIG. 1

Distribution of non-anatomical areas of hypalgesia in cases of conversion hysteria. The predominant site of subjective symptoms is stated beneath the patient's age.

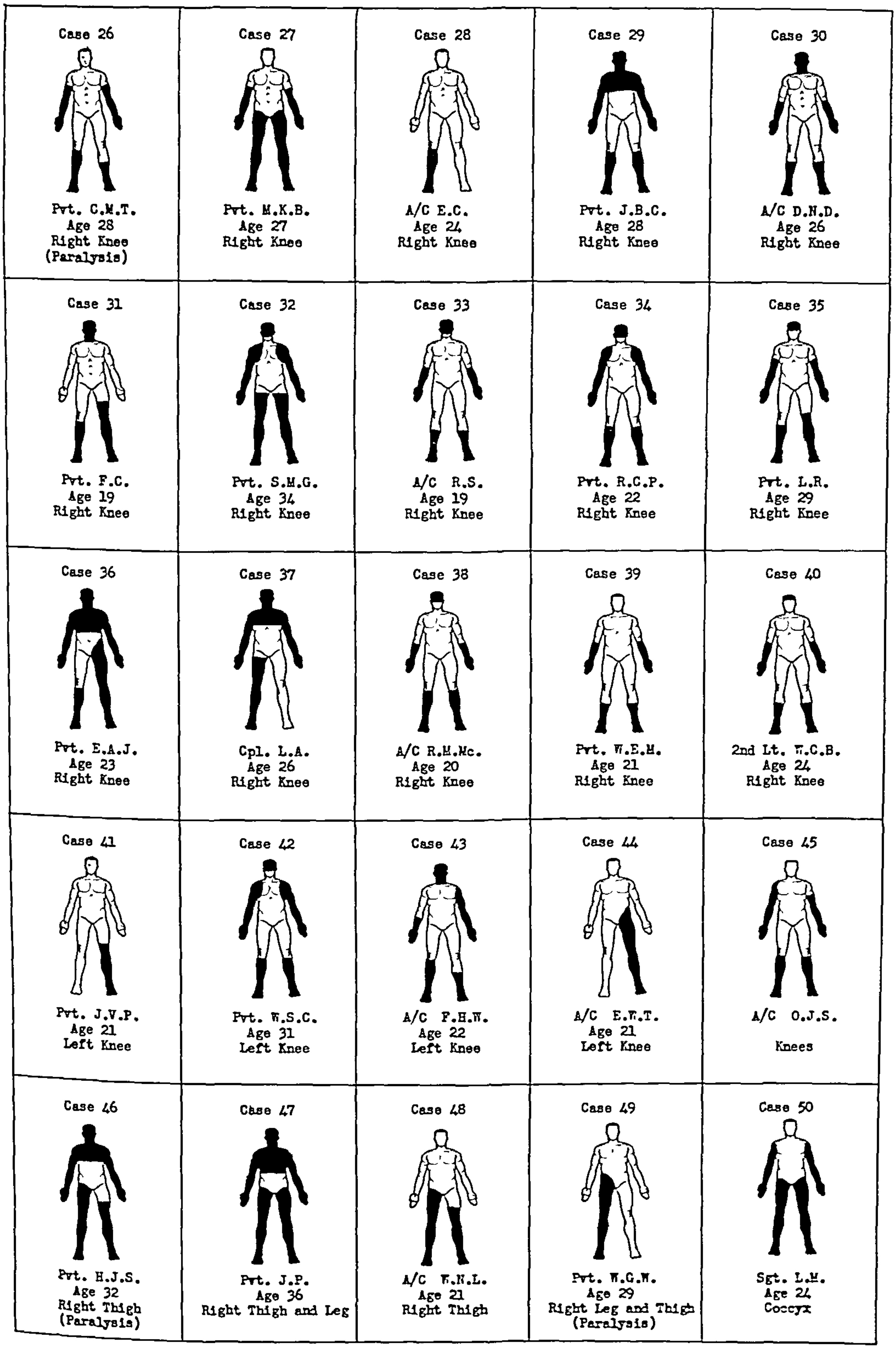

Fig. 2

Patterns of circumferential hypalgesia.

side of the body in eleven cases, and to the left side in four. In fifty-two cases part or all of the head was involved; this included the conjunctiva, when the level extended below the eyes. While the site of the musculoskeletal symptoms did not often appear to dictate the pattern of the sensory changes, all cases in this series which had extremity symptoms had hypalgesia in those extremities. There was a tendency for unilateral symptoms to be on the right side. Of the nineteen cases with unilateral knee symptoms, fifteen were on the right and only four on the left. Of the five cases with symptoms in one foot, all were on the right.

Sixty-eight of the patients were enlisted men, thirty-one were aviation students and cadets, and one was an officer. In the ten cases of hysterical paralysis the involvement was in the extremities, and was distributed as follows: toes, one case; right foot, two cases; right knee, one case; right leg and thigh, one case; right thigh, one case; left shoulder, two cases; left forearm, one case; right forearm, one case. Of these cases, four were of short duration and responded well to treatment; six were of many months' duration and were resistant to therapy.

COMPARISON OF PSYCHOGENIC AND ORGANIC MUSCULOSKELETAL SYMPTOMS

Since the majority of psychogenic musculoskeletal symptoms are referred to joints, emphasis will be placed upon differential joint diagnosis.

When the physical symptoms are out of proportion to the objective findings, the possibility of a psychogenic disorder must be entertained. In the majority of cases in this series with joint symptoms, there were no positive objective findings. A roentgenogram of the joints was usually made, however, and a sedimentation rate was obtained to make certain that no organic lesion was developing and to reassure both the doctor and the patient. Diffuse tenderness is not an unusual psychogenic symptom. This type of tenderness is not limited to anatomical structures, however, and may vary in its distribution from day to day. It may involve the entire back or an entire extremity. Those regions of the body which are normally quite tender must not be recorded as sites of point tenderness.

Muscle spasm may unconsciously be simulated by the neurotic individual, who may hold a part of his body in one position for a long period of time: the knees may be held rigidly extended, the foot in equinus, the spine bent forward, the head bent to one side, or a shoulder elevated. In these cases the joints may become stiff and the muscles atrophied, thus presenting a secondary organic problem.

In psychogenic disorders, when a joint is flexed passively, resistance may be encountered after the first few degrees of motion and the patient may state that he cannot move the joint farther. However, if a steady, firm pressure is employed, the joint will usually continue to flex, and usually will proceed slowly and jerkily to the normal degree of flexion. In striking contrast is the finding in joints having organic lesions. When substantial resistance and pain are met during the process of flexing the joint, there is progressive muscle spasm; and only rarely can the patient tolerate having the joint flexed beyond a few more degrees.

Radiating pains, with a consistent anatomical pattern of distribution in one extremity, are likely to be organic. Bizarre pains, radiating simultaneously into two or more extremities or up the spine and presenting changeable patterns, have usually proved to be psychogenic. A steady, firm resistance offered by some neurotic patients to all passive movements of the lower extremity should not be mistaken for positive leg signs. Line tenderness of the type that occurs along an inflamed nerve trunk—for example, the sciatic nerve—is not likely to be simulated by a psychogenic problem. An entire extremity may become tender on a psychogenic basis, however, and if only a nerve trunk or other solitary structure is palpated, a misinterpretation might follow.

Vasomotor disturbances may become pronounced in the neurotic patient. It is a frequent complaint that a part of the body, usually an extremity, is cold and "dead" for want of good circulation. If symptoms are entirely on a neurotic basis, the circulation, except for vasomotor instability, would be found to be unaltered.

Differentiation of organic from hysterical paralysis may be difficult. In many instances a psychogenic paralysis develops immediately after an accident and may resemble a serious nerve or brain injury. Hysterical paralysis may be either flaccid or spastic, but the flaccid type is more common. Its response to psychotherapy, faradic stimulation, or narcosynthesis may be spectacular. Hysterical paralysis, like hysterical hypalgesia, is bizarre and non-anatomical in pattern. The many tests for identifying localized nerve injuries are useful in differential diagnosis, but need not be reviewed here.

It is a mistake to assume that muscle atrophy cannot occur in hysterical paralysis; definite atrophy of all structures in entire extremities may occur, and may lead to organic changes which pose many orthopaedic problems.

Subjectively, there are important differences between organic and psychogenic musculoskeletal symptoms, which deserve emphasis. The exact time of onset and the character of psychogenic conditions are often vague, but frequently they are related to a period of great emotional stress. Recurring episodes of symptoms over a period of years, beginning in childhood or early adult life, is the rule in conversion hysteria. It is impressive to examine a joint, or any other part of the musculoskeletal system which is claimed to have been the source of much distress and disability for many years, and to find no objective evidence of disease on physical examination or by laboratory test. In such instances an examiner may visualize some unfamiliar deep-seated musculoskeletal disease process. It is commendable to search diligently for organic lesions; but a tiny marginal osteophyte, a slight malalignment of a joint, or a minor congenital anomaly has been held up all too often as the etiology of purely neurotic musculoskeletal symptoms.

That a minor as well as a major organic lesion can precipitate a neurosis is frequently observed. The neurotic patient often begins his story by telling about a sprained ankle, a back strain, or a "twisted knee". He may ascribe all of his subsequent troubles to this organic lesion, which usually healed promptly and left no organic evidence. These individuals have usually tried a wide variety of orthopaedic procedures, which are despairingly described as having offered no lasting benefit. The treatments received during episodes of neurotic musculoskeletal symptoms are given some credit, and this is particularly true of that therapy in use toward the end of one or more episodes. These patients, so trying to organicists, refuse to remain "cured". Each period of emotional chaos in their lives ushers in an episode of neurotic somatic symptoms.

There is an important group of "orthopaedic neurotics" who have both a serious organic disability and a complex psychogenic musculoskeletal disorder, and they may present difficult problems in diagnosis and therapy. The psychogenic and organic symptoms overlap in such a way as to make it impossible on occasions to know where the organic ends and the psychogenic begins. Our attempts at a rigid separation of these two sources of symptoms are, however, not always warranted. Abnormal physiological and psychological responses go hand in hand. Psychosomatic medicine is not a new kind of medicine, but medicine in a wider perspective. From a practical standpoint, however, we must very often separate the organic from the psychological in order to institute proper treatment. Both types of symptoms must be treated simultaneously and each must be given its deserved quota of attention.

During episodes of acute, painful, disabling organic disease—particularly if the patient is bedfast—neurotic symptoms may be minimal. If, during the convalescent period, the patient is permitted to spend endless hours in introspection, the neurotic element becomes dominant. If unrecognized, unappreciated, and untreated, the stage may then be set for months, years, or even a lifetime of disability.

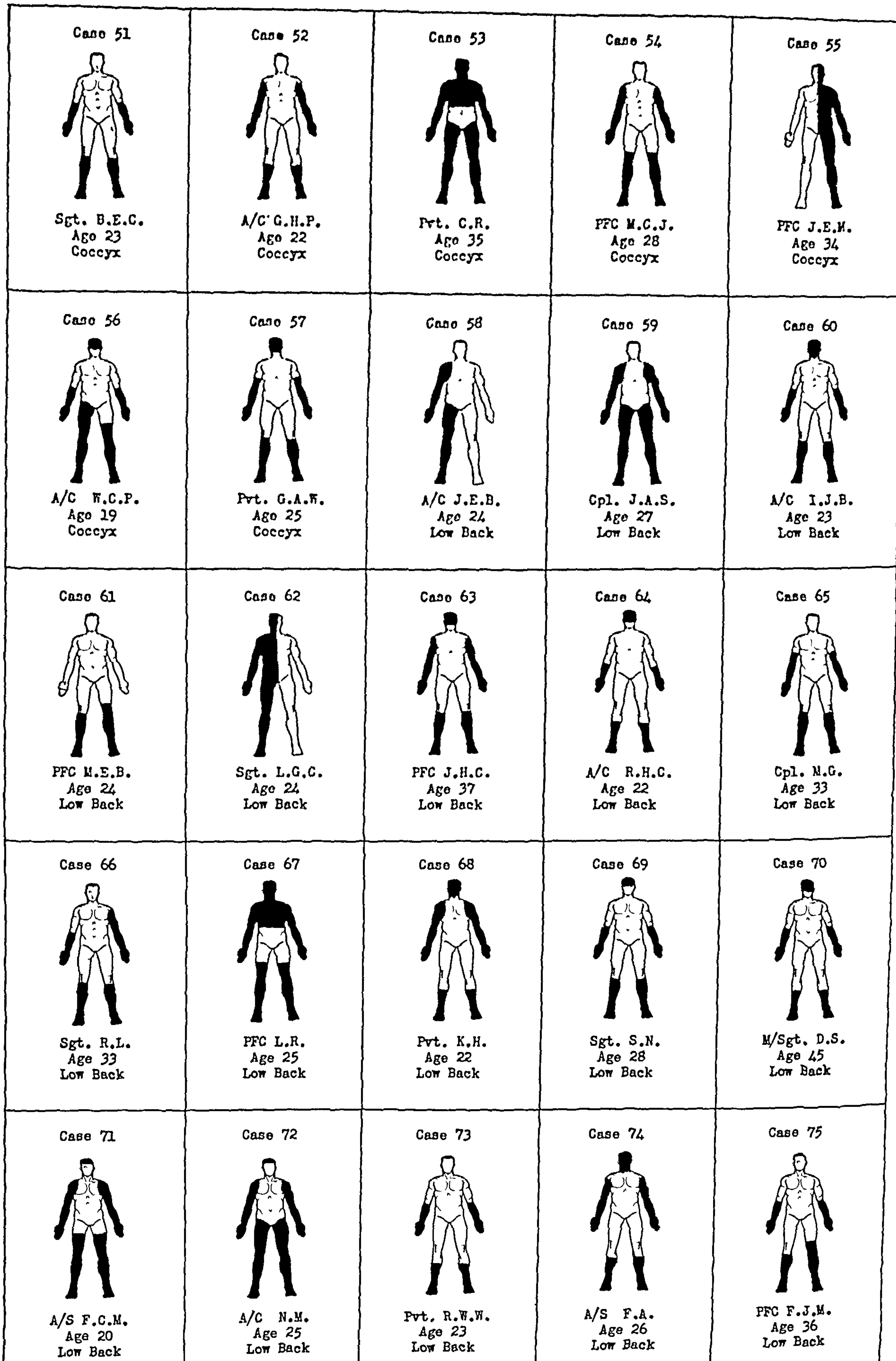

FIG. 3

Patterns of circumferential hypalgesia.

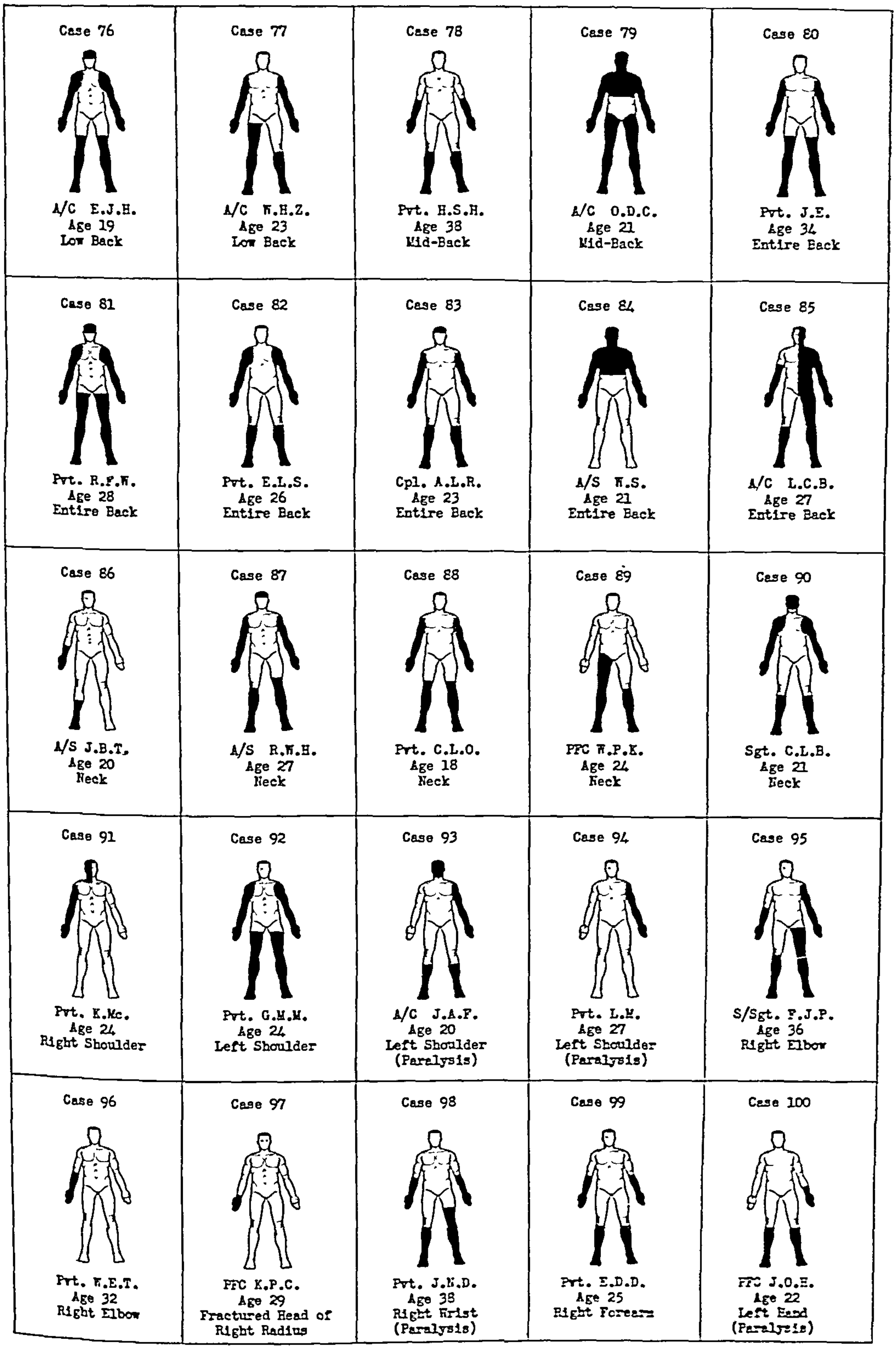

FIG. 4

Patterns of circumferential hypalgesia.

Sites of Neurotic Musculoskeletal Symptoms

Although no part of the body is exempt, certain sites in the musculoskeletal system are particularly apt to become foci of neurotic symptoms. Such sites are the sacral region, the coccyx, knees, feet, neck, and shoulders. The site of a healed fracture, particularly if associated with a skin scar, is often the focus of neurotic symptoms.

Although in some instances it is impossible to uncover any explanation of the particular site in the musculoskeletal system at which the symptoms occur, in a high percentage of cases combined orthopaedic and psychological histories will identify the focus as the site of previous organic symptoms, either in the patient himself or in someone close to him,—for example, a mother, father, or brother. Psychogenic symptoms frequently appear during convalescence from an organic musculoskeletal lesion, and may tend to simulate the previous organic symptoms, thereby perpetuating much of the original disability for weeks or years after the organic lesion has healed. After experiencing a frightening accident and simultaneously incurring major or minor musculoskeletal lesions, the patient may periodically relive the experience and the musculoskeletal symptoms, as a neurotic manifestation.

THERAPY AND DISPOSITION

The psychiatrists can care for the complex psychological problems, but for a large group of patients, particularly those with combined psychogenic and organic musculoskeletal symptoms, the orthopaedic surgeon will have to assume responsibility for the psychotherapy. Just as there is an acceptable abbreviated form of psychological history, there is also worth-while abbreviated psychological therapy, referred to as superficial or minor psychotherapy. This form of therapy includes evaluation and advice regarding correction of environmental conflicts; the giving of insight into the significance and the character of the existing psychological symptoms, and the explanation of any coexistent organic symptoms; identification and elimination of the underlying conflict, when possible, and when not possible the elimination of aggravating factors; administration of sedatives for insomnia or for chronic fatigue; and the prescription of occupational therapy when indicated.

In setting the stage for psychotherapy, it is of the utmost importance that the physician have the proper attitude toward the patient's psychological problem. To treat neurotic and maladjusted individuals as though they were weaklings or malingerers is to slam the door upon psychotherapy. The necessity for gaining the patient's confidence, prior to attempting psychotherapy, is self-evident. Psychiatrists refer to this as establishing rapport.

Psychological disorders uselessly dissipate the patient's energy. If the amount of energy lost is slight or moderate, the patient may be able to live an approximately normal life. Under this circumstance he may be considered as emotionally compensated. If additional emotional stress is incurred, he not only needlessly dissipates more of his energy, but may transform his emotional chaos into physical symptoms, and then may be said to be in a decompensated stage. Ordinarily such patients can be brought back to their previous state by such relatively simple measures as correcting an environmental conflict. The neurotic individual may be forced to lead a protected, carefully regulated life in order to remain "compensated". Those who cannot be cured must be taught to live with their neuroses. It has been gratifying to find that many soldiers who were weighed down by fixed neuroses have been able to carry on after they have been helped to solve some of their environmental problems. Their psychogenic musculoskeletal symptoms have not always subsided, but frequently have diminished to the extent that the patient could do his job.

Response to treatment depends upon many factors. Some patients develop symptoms

only under the most profound mental and physical stress. In such patients the response to treatment and the prognosis are better than in individuals who develop neurotic episodes under the ordinary stresses of life. The term "threshold of conversion" may be used to visualize the transformation of emotional disturbances to physical symptoms. Just as individuals have a different threshold of pain, they also have a different threshold at which they are overwhelmed by psychological stresses. Experiences in this War have taught psychiatrists that even the hardiest soldier has a breaking point and will become a psychological casualty, if the pressure becomes sufficiently great and prolonged. In this type of case the good response to early treatment and the good prognosis are in striking contrast to conditions found when there is a low threshold of conversion.

Very often there is both organic and psychogenic musculoskeletal pain, and progress in psychotherapy may be retarded or postponed until the organic lesion has been recognized and treated successfully. Analgesics which relieve the organic pain and have little effect on the psychogenic pain may be helpful in evaluating the extent of the organic symptoms.

Neuroses secondary to and precipitated by organic lesions can often be prevented. A patient should not be told that his illness or injuries are serious and may result in permanent disability until there is no doubt that it is true. Bad news, true or false, can damage the patient's mental health.

As far as possible, patients with neurotic musculoskeletal symptoms are treated in the dispensaries in order to keep hospital admissions to a minimum. Neurotic patients admitted to the Orthopaedic Section are studied as rapidly as possible to rule out organic lesions, and disposition is made without delay. Before he is released, the patient is firmly and positively reassured that no musculoskeletal organic lesion is producing his symptoms.

Prior to doing elective major surgery, a psychological evaluation of the patient should be obtained. As Wechsler has said in referring to unwarranted surgery: "Heroic operations do violence to patients and confirm their neuroses".

During convalescence an effort should be made to detect and correct bad psychological trends. By personally visiting the patient at close intervals, such trends can either be prevented or can be discovered early and treated. Keeping the patient well informed as to his condition, and reassured when progress is slow, does much to prevent psychological symptoms.

Of profound importance is the necessity for keeping the patient's mind and body as busily occupied as is feasible during convalescence. Menninger[5] has emphasized that: "Morbid preoccupation, and monotonous, empty days in a hospital extend and increase mental disability". The splendid convalescent training programs of the Armed Services have been of inestimable value in preventing psychological disorders during convalescence.

The most effective time to treat emotional problems is in their incipiency. In caring for flying personnel, flight surgeons do excellent work in both the prevention and the early treatment of psychological problems. They have long appreciated the importance of good mental health.

It is not enough to tell the neurotic patient that he has a neurosis and should snap out of it. His will power is not great enough to overcome his problem, so long as he does not have insight into the nature of the problem and the character of his symptoms. Giving the patient insight is best deferred until a thorough study of his condition has been made, and his confidence has been secured.

In the presence of anxiety, insomnia, and chronic fatigue, temporary administration of the barbiturates frequently plays an important part. Conflicts and frustration often follow in the wake of long-standing fatigue. Many an anxiety or hysterical state has been prevented by the judicious use of the barbiturates.

Aggressiveness in attaining relief often leads the neurotic patient to accept unscientific therapy, particularly if he is assured that he has an organic lesion underlying his symp-

toms. Except when neuroses are hopelessly fixed, palliative therapy, such as periodic body manipulations or pink pills, is condemned. To treat a disorder as physical when it is psychical can do much harm.

Whenever an environmental conflict aggravates or precipitates an emotional problem, an effort should be made either to alter the environment or the patient's attitude toward it. Reassignment helps many soldiers. Many neurotic individuals are capable of doing important work, if properly handled. Another trial of duty is indicated whenever there is any doubt as to the necessity for separating a soldier from the Service. Patients are urged to carry on and are firmly informed that their work will do their musculoskeletal systems no harm; rather, giving in to every symptom is the real source of harm.

In the past we have usually leaned far to the organicist's approach; we must not now lean too far the other way. In the words of Portis: "One cannot warn too emphatically against making the psychotherapeutic approach a new panacea for all patients".

ILLUSTRATIVE CASES

Case 7—Corporal M. L. G., aged thirty-six. The patient had had painful feet for many years, but they became much worse after he entered the Army. He had a "snowshoe" gait. No relief was obtained from supports or corrective shoes. The feet felt numb and stiff. There was normal mobility of all joints, also good mechanics. There was no tenderness or muscle spasm. Hypalgesia was limited to the feet and ankles. The patient made a very poor adjustment to the Army; a diagnosis of conversion reaction was made by the psychiatrist.

Case 21—Corporal E. O. S., aged twenty-nine. The patient sprained his right ankle in June 1942, and in two weeks was able to walk well. There were no unusual findings; roentgenograms were negative. Increasing pain then developed in the ankle and foot, and crutches became necessary. Paralysis of the foot followed. At six different hospitals the patient received many forms of physical therapy, casts, splints, and a brace. Physical examination disclosed normal bones and joints. There was partial flaccid paralysis of the right leg. The foot was held in plantar flexion and inversion. There was hypalgesia of the right leg, ending sharply at the knee. The patient responded to psychotherapy and faradic stimulation. A psychiatric examination revealed emotional immaturity, conversion reaction, and hysterical paralysis.

Case 23—Private A. J. C., aged twenty-five. At the age of nine the patient was frightened by a razorback hog and incurred a sprained left ankle. Periodically since, during periods of nervous strain, there had been disabling pain in the ankle and inability to stand or walk more than briefly. The ankle was said to feel tense and not under complete control. The left ankle was normal clinically and by roentgenogram. Hypalgesia was present in all four extremities and in the scalp. There was no evidence that the site of the subjective symptoms dictated this particular distribution of hypalgesia. The patient relives his original experience when under emotional stress.

Case 26—Private C. M. T., aged twenty-eight. Pain in the right shin, from knee to above ankle, was a complaint during activity. The patient described the pain as being like pegs driven into his shin. He walked with a stiff right knee and a hobbled gait. There was no evidence of an organic lesion. The psychiatric report described a "ceremonial" gait. There were many neurotic traits. The hypalgesia was not limited to the right leg, but involved all four extremities. An hysterical spastic paralysis held the right knee fixed in extension.

Case 28—Aviation Cadet E. C., aged twenty-four. The patient twisted his right knee in a broad jump and split the right medial meniscus. A bucket-handle type of torn medial meniscus was removed in its entirety. Convalescence was uneventful and the patient was cooperative. Upon return to duty many bizarre symptoms appeared in the right knee (numbness, throbbing, tingling, and a sense of "giving way"). Examination of the knee disclosed normal motion and stability, no swelling, and excellent musculature. The patient was eliminated as a cadet. He improved under reassurance and reassignment. The psychological examination disclosed a deep-seated fear of flying.

Case 32—Private S. M. G., aged thirty-four. The patient had had frequent episodes of pain in his right knee for seventeen years. There was no limitation of motion and no instability. Part of the right tibial tubercle was removed in 1942 for unhealed Osgood-Schlatter's disease. No relief was obtained from the operation, from numerous subsequent casts, or from physical therapy. There was never any locking of the knee, but many bizarre symptoms. Examination was entirely negative, except for hypalgesia, involving all of the extremities and most of the head. Further surgery, casts, or physical therapy would probably have aggravated and further fixed this patient's conversion reaction. A psychiatric

history indicated that this soldier had made an unsatisfactory adjustment to his environment since childhood

CASE 41—Private J V P , aged twenty-one A torn medial meniscus was removed from the left knee after three years of symptoms Convalescence was uneventful until it was time to return to duty Pain, weakness and stiffness in the knee then developed The patient could not keep his knee in one position more than a few minutes, because it would "go to sleep" and feel dead He also complained of hyperhidrosis and insomnia The patient was reclassified and given ground duty Hypalgesia was present, as shown in Figure 2 The soldier had an anxiety state, which subsided after superficial psychotherapy.

CASE 44—Aviation Cadet E W T , aged twenty-one Three months after removal of a torn left medial meniscus, weakness in the left knee suddenly developed, and the patient was unable to walk A locked knee was simulated, and an exploration was recommended by the ward officer Examination revealed diffuse weakness of the entire extremity and hypalgesia to the level of the iliac crest Further study disclosed emotional instability, "nervous spells", and somnambulism The patient's father had had several "nervous breakdowns" The knee symptoms subsided with psychotherapy The soldier was discharged from Service by advice of the Psychiatric Section, due to pronounced emotional instability and neurotic background

CASE 55—Private First Class J E M , aged thirty-four (actor) The patient complained of pain in the coccyx and in the left side of the back, from sacrum to neck The symptoms had been present for six years, since a fall down several steps at a motion-picture studio There was frequent tingling and numbness of the entire left side of the body Sleep was disturbed, and the patient had no energy There was left hemiplegic hypalgesia Anxiety symptoms and a conversion reaction were combined in this case The patient was a failure both as an actor and as a soldier, and had a poor capacity for adjustment to adult life

CASE 65—Corporal M G , aged thirty-three (musician) Pain in the lower back, radiating down both lower extremities posteriorly to the ankles, had been present since a fall during a handball game in 1934 The patient had had innumerable types of therapy, except psychotherapy Belts and casts increased the back pain and produced abdominal pains The patient was tense, "nervous", and irritable most of the time Back pain was precipitated by episodes of "nervousness" He was unable to stand or to sit long in any one position Physical examination and roentgenograms of the spine were negative Hypalgesia was present in all extremities, as shown in Figure 3 There were numerous neurotic traits, dating back to childhood There was no response to psychotherapy

CASE 74—Aviation Student F A , aged twenty-six Low-back pain developed soon after the patient entered the Army, eighteen months prior to Hospital admission The pain radiated "down both the bones" of the thighs to the knees He had camptocormia, which became pronounced during hospitalization The condition was treated for several weeks as a lumbosacral strain, during which time all symptoms were aggravated Roentgenograms were negative Hypalgesia was present, as shown in Figure 3 There was normal mobility of the spine Response to a brief period of psychotherapy was poor

CASE 88—Private C L O , aged eighteen (negro) The patient fell off a cotton bale in 1941, landing on his head No serious injury resulted, but the neck was moderately painful and he experienced a "lump in the throat" for several days He continued to have pain and "popping" in his neck, the pains would radiate up the neck and over the top of the head, to end in his eyes There were frequent episodes of "nervousness", during which the globus hystericus would return and the neck pain would reappear The patient had constant fatigue, and could do only light work He had been told that he had arthritis, and this caused him much worry Roentgenograms were negative and there was normal mobility of the cervical spine The patient had the emotional maturity of a child Hypalgesia was present in all four extremities, but failed to involve the neck or any part of the head

CASE 93—Aviation Cadet J A F , aged twenty The patient had difficulty with his studies and many fears about flying He was in a constant state of nervous tension, gradually became exhausted, and could not sleep An acute anxiety state suddenly developed, during which there was diffuse pronounced weakness and aching of the entire left upper extremity He complained of a spot on the scalp, the size of a silver dollar, that burned and frequently "felt like it would explode" There was pronounced intention tremor of the left upper extremity There was hypalgesia of left upper extremity, legs and head, as shown in Figure 4 No orthopaedic or organic neurological abnormality was found The patient was promptly transferred to the Psychiatric Section, where he was soon relieved of the anxiety state and hysterical paralysis by psychotherapy

CASE 98—Private J N D , aged thirty-eight The patient complained of pain and weakness of the shoulders arms and entire spine for twelve years All symptoms increased during twelve months of Army service He had a permanent Kitchen Police assignment Ten days prior to admission to the Hospital while peeling potatoes, the patient's right hand suddenly became paralyzed There was normal finger and thumb action but all ability to extend the wrist was lost No orthopaedic or neurological

problem could be identified. The patient responded to psychotherapy. His intellectual and emotional maturity were those of a ten-year-old child.

SUMMARY AND CONCLUSIONS

1. There is a psychiatric aspect to orthopaedic surgery which should receive increased recognition.

2. A psychosomatic diagnosis must be made on the basis of positive findings, and not alone by excluding organic entities.

3. Psychogenic musculoskeletal symptoms were found in 11.1 per cent. of the patients hospitalized in the Orthopaedic Section. Among patients in the Orthopaedic Out-Patient Department, the incidence of psychological disorders was over 25 per cent. Approximately 1,000 patients with psychogenic musculoskeletal symptoms were studied.

4. Based upon the relationship to organic symptoms, three types of psychological problems were observed: (1) those occurring without known relationship to an organic lesion; (2) those secondary to and accompanying an organic lesion; and (3) those perpetuating symptoms of a healed organic lesion. Based upon psychiatric symptoms, the types seen were: (1) conversion reactions, (2) anxiety states, and (3) psychogenic elaboration of organic symptoms.

5. An abbreviated psychological history was obtained from all patients in whom the source of symptoms was obscure and the objective findings were bizarre.

6. Musculoskeletal pains of uncertain origin should be analyzed in terms of their exact character. Neurotic pains frequently include a sense of pressure, tension, or numbness. Bizarre radiating pains, particularly those radiating from a distal point proximally, are often psychogenic. Psychogenic and organic musculoskeletal symptoms are compared.

7. There may be several objective findings to identify a neurosis, or there may be none. The findings most often encountered include circumferential hypalgesia, hysterical paralysis, coarse intention tremors, and anxiety symptoms.

8. In 100 consecutive cases in which conversion reactions included circumferential hypalgesia, the patterns of hypalgesia are presented. Ten of the 100 patients had hysterical paralysis.

9. Sites of neurotic musculoskeletal symptoms are listed, together with some of the factors determining these sites.

10. The scope and use of superficial psychotherapy are discussed.

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PATHOMECHANICS OF THE HIP AFTER THE SHELF OPERATION

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It has been observed at this Clinic that many patients with dislocation or subluxation of the hip, who have been treated by the shelf operation, continue to limp, even if the shelf is strong and well built. This observation has been made previously by several authors, including Ober and Therkelsen, but it has frequently been overlooked.

The present study is based upon sixty-eight patients, eleven males and fifty-seven females, with dislocation of the hip. Fifty-nine of the dislocations were unilateral and nine were bilateral, making a total of seventy-seven dislocated hips on which the shelf operation was used in the Orthopaedic Department of the State University of Iowa. Thirty-seven dislocations were of the right hip and forty were of the left. There were sixty-one congenital dislocations; seven of these were of prenatal origin (Table I, Type A) and fifty-four were postnatal (Table I, Types B and C). Nine were congenital subluxations. Three were subluxations of paralytic origin, and one was a dislocation due to spastic paralysis. Three dislocations followed a suppurative arthritis.

The average follow-up period was seven years, with a minimum of four years and a maximum of twenty years. The ages of the patients at the time of operation varied from two and one-half years to thirty-six years.

Of the seventy-seven dislocated hips, fifty-two were dislocated upward—the so-called anterior dislocation. Thirteen were posterior dislocations, and twelve were subluxations. The small number of posterior dislocations in this series is due to the policy of the Clinic to use a subtrochanteric osteotomy in the treatment of most cases of irreducible posterior dislocation.

In forty-two hips the shelf was built over the femoral head, which had been placed in the primary acetabulum. In twenty-three cases the shelf was built with the femoral head in a secondary acetabulum. In twelve hips, most of which were dislocated posteriorly, the femoral head was completely dislocated and there was no secondary acetabulum.

In twenty-seven patients with redislocation or subluxation of the hip, the shelf operation was performed from one month to sixteen years after closed reduction. In fifty hips it was performed as a primary operation, with or without concomitant closed reduction.

In five patients the greater trochanter was detached, together with its muscle insertions, at the time of the shelf operation and was transposed from one to three centimeters down over the lateral aspect of the femur. In four of these patients the femoral head was reduced into the primary acetabulum at the beginning of the operation. In the other patient the femoral head was left in the secondary acetabulum.

RESULTS

Severin's standards were used to evaluate the anatomical results of the shelf operation. The standards for the functional results are the same as those previously used by the author.[4]

The *anatomical* results of treatment are indicated as follows: Group I, well-developed hip joints; Group II, moderate deformity of the femoral head, neck, or acetabulum in an otherwise well-developed joint; Group III, dysplasia, not subluxation; Group IV, subluxation; Group V, femoral head in a secondary acetabulum in the upper part of the primary acetabulum; Group VI, redislocation. The *functional* results of treatment are

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TABLE I

ANATOMICAL AND FUNCTIONAL RESULTS AFTER SHELF OPERATION FOR DISLOCATION OF THE HIP

Type of Dislocation	Anatomical Results	Functional Results: Shelving with Femoral Head in Primary Acetabulum — Group 1 No Symptoms	Group 2 Slight Pain	Group 3 Limp	Group 4 Limp and Limitation of Motion	Group 5 Limp and Pain	Group 6 Limp, Limitation of Motion, and Pain
Type A Prenatal dislocation (7 hips) 2½ to 5 years	I Well-developed hip joint						
	II. Moderate deformity of hip						
	III. Dysplasia, not subluxation				1		
	IV. Subluxation						
	V Head in secondary acetabulum						
	VI Redislocation						
Type B Postnatal dislocation (23 hips) Patients under 6 years	I Well-developed hip joint	1					
	II Moderate deformity of hip	2		1			
	III. Dysplasia, not subluxation	1	1	1		2	
	IV. Subluxation			1	1		
	V Head in secondary acetabulum			3	2		2
	VI Redislocation						
Type C Postnatal dislocation (31 hips) Patients over 6 years	I Well-developed hip joint						
	II Moderate deformity of hip	1					
	III Dysplasia, not subluxation			2	3		1
	IV. Subluxation						
	V. Head in secondary acetabulum			1	1		
	VI. Redislocation						
Type D Subluxation (9 hips) All patients over 6 years	I Well-developed hip joint						
	II Moderate deformity of hip				1		
	III Dysplasia, not subluxation		2				1
	IV Subluxation						
	V Head in secondary acetabulum			2	2		1
	VI Redislocation						
Type E Paralytic subluxation (3 hips) Over 10 years	III Dysplasia, not subluxation			1			
	V. Head in secondary acetabulum			1	1		
Type F Spastic paralysis (1 hip) 11 years	IV. Subluxation				1		
Type G Following suppurative arthritis (3 hips) 3 to 8 years	IV Subluxation						
	V. Head in secondary acetabulum						
		5	3	13	13	2	5
Totals 77 hips		41 hips *					

* In one hip of this group fusion resulted.

TABLE I (*continued*)

Functional Results												
Shelving with Femoral Head in Secondary Acetabulum						Shelving with Femoral Head in No Acetabulum						
Group 1 No Symptoms	Group 2 Slight Pain	Group 3 Limp	Group 4 Limp and Limitation of Motion	Group 5 Limp and Pain	Group 6 Limp, Limitation of Motion, and Pain	Group 1 No Symptoms	Group 2 Slight Pain	Group 3 Limp	Group 4 Limp and Limitation of Motion	Group 5 Limp and Pain	Group 6 Limp, Limitation of Motion, and Pain	Total Hips
												1
			3					1	1			5
												1
												3
												5
		1						1				4
			1		1			1				10
												1
												6
		1										1
		5	2	1	3				2		2	17
			1		2				1			4
												1
												3
												5
												1
												2
												1
										1		1
			1						1			2
		7	8	1	6			3	5	1	2	74
22 hips **						11 hips ***						

** One patient of this group died a few hours after a shelf operation.
*** Postoperative infection, in one hip of this group, resulted in fusion.

given the following designations: Group 1, no symptoms; Group 2, slight pain in the hip on excessive walking; Group 3, limp, free motion, and no pain; Group 4, limp and limitation of motion, but no pain; Group 5, limp and pain; Group 6, limp, limitation of motion, and pain.

Telescoping: Before the shelf operation was performed, the telescoping sign was not present in thirteen hips, but in the remaining sixty-four hips this sign was observed. In fifty-one of the latter group the telescoping disappeared completely after the shelf operation; in eleven there was marked improvement; and in only one case of posterior dislocation, in which the shelf became absorbed, did the telescoping persist.

Trendelenburg Sign: In four hips the Trendelenburg sign was negative before the shelf operation was performed, and continued to be negative thereafter. The Trendelenburg sign was positive in the remaining seventy-three hips. In eight of these the Trendelenburg became negative from two to six months after the shelf operation and remained negative. In three patients there was marked improvement. In sixty-one hips the Trendelenburg sign continued to be positive.

Pain: Fifty-one hips were free of pain before the shelf operation and remained pain-free after the operation. In seven cases there was pain in the hip on admission, which disappeared after the operation. Four patients complained of pain and obtained no relief after the shelf operation. Fourteen hips were pain-free before the operation and became painful after it. Of this last group, eight patients were over ten years of age, and the shelf operation was performed after forceful open reduction, following the preoperative application of traction for a few weeks. In two of these patients the acetabular cavity was reamed and deepened at the time of the operation, resulting in great stiffness of the hip. The other six patients were under ten years of age, but all had posterior dislocations.

In Table I are shown the anatomical and functional results in the different types of dislocation, arranged according to the age of the patient and the position of the femoral head at the time of the shelf operation. Type A includes the dislocations which occurred before birth. Type B includes the patients under six years of age who were born with a dysplastic hip which showed the signs of predislocation. Complete dislocation took place during the first months of life. Type C includes postnatal dislocations in patients who were over six years of age at the time of the shelf operation. In Type D, or subluxation, the femoral head was situated in the upper portion of a deformed acetabular cavity, but was not completely dislocated. The patients in Type E had paralysis of the gluteal muscles, and subluxation of the hips occurred because of lack of muscle support. The patient in Type F had spastic paralysis with marked spasticity of the adductors; weakness of the gluteal muscles resulted in a dislocation of the hip. The patients in Type G had suppurative arthritis with pathological dislocation of the hip. The final functional results in the seventy-seven hips, as compared with the initial symptoms, are shown in Table II.

Of the thirteen hips dislocated posteriorly, it was possible in three instances to perform an open reduction, together with the shelf operation. Two of them resulted in hips of anatomical Group III,—one with no symptoms and the other with a slight limp. The other hip resulted in Group 4, with limp and limitation of motion. In the remaining ten cases the shelf operation was performed with the femoral head dislocated, either in a secondary acetabulum or in no acetabulum at all. In these cases the functional results were poor, except for two cases in which the dislocated femoral head was transposed anteriorly at the time of the shelf operation, resulting in slight limp but no pain.

In two hips the operation resulted in fusion. In one patient with prenatal dislocation, two and one-half years old, postoperative infection occurred. The other patient, fifteen years old, had a high anterior dislocation; treatment was by open reduction and the shelf operation.

One eight-year-old patient with a postnatal dislocation died of surgical shock a few ours after the shelf operation.

TABLE II

FINAL FUNCTIONAL RESULTS OF SHELF OPERATION IN PATIENTS WITH DIFFERENT INITIAL SYMPTOMS

Symptoms Present Before Shelf Operation	Final Functional Results							
	Group 1 No Symptoms	Group 2 Slight Pain	Group 3 Limp	Group 4 Limp and Limitation of Motion	Group 5 Limp and Pain	Group 6 Limp, Limitation of Motion, and Pain	Fusion	Patient Deceased
Group 2 Slight pain in hip on excessive walking (3 hips)		1				2		
Group 3 Limp, free motion, and no pain (66 hips)	5	1	20	26	3	8	2	1
Group 4 Limp and limitation of motion, but no pain (3 hips)						3		
Group 5 Limp and pain (5 hips)		1	3		1			
Totals: 77 hips	5	3	23	26	4	13	2	1

Four hips redislocated a few months after the shelf operation; three were posterior dislocations and the other was an anterior dislocation. In three of these cases the shelf became completely absorbed, and in the other case the femoral head was markedly anteverted and redislocated anteriorly to the shelf.

COMMENT

The results given here and in Tables I and II indicate that all the patients treated by the shelf operation, performed with the femoral head situated in a secondary acetabulum or in no acetabulum, continued to limp.

Of the forty-two shelf operations performed with the femoral head in the primary acetabulum, a normal hip joint developed in only one, and in five the final result was a moderate deformity of the hip. One hip in a fifteen-year-old patient became fused after forceful reduction and a shelf operation. In the remaining thirty-five hips the femoral head became displaced outwardly after the shelf operation, resulting in dysplastic hips (Group III) or subluxations. Frequently, however, the femoral head finally became stabilized in a secondary acetabulum situated somewhat above the primary acetabulum and away from the line of gravity. From the functional point of view, in only eight patients did the limp disappear,—five hips became symptomless and three were only slightly painful on strenuous walking. The remaining thirty-four patients continued to limp, some of them developed limitation of motion, and a few had pain.

After the shelf operation, then, the femoral head became stabilized, either in the primary acetabulum or in a secondary acetabulum; the telescoping disappeared; but most of the patients continued to limp. If the strength of the hip muscles has been preserved by careful surgery, the poor functional results of the shelf operation, performed with the head placed in the primary acetabulum, can only be explained on the basis that the hip with a surgically created shelf is mechanically defective. Normally, the hip joint is considerably separated from the line of gravity, and consequently the gravital forces determine a rotatory effect upon its center of motion. The rotatory moments developed by the gravital forces upon any joint are equal to the product of body weight times the per-

pendicular distance from the center of motion of the joint to the line of gravity.[7] If, after a shelf has been built, the center of motion of the hip becomes abnormally separated from the line of gravity, the rotatory moments acting upon this hip will be greatly increased.

In all of the anteroposterior roentgenograms of these patients, measurements were made of the perpendicular distance between the center of the femoral head and a line drawn through the longitudinal axis of the sacrum, which represents approximately the line of gravity. This distance is the so-called Y coordinate for the hip joint, and in normal hips it varied from 5.5 centimeters in a child, two and one-half years old, to 9 centimeters in a woman of twenty-eight. The Y coordinate is slightly larger in females than in males. The normal value of the Y coordinate of the center of the hip joint, according to the calculations of Braune and Fischer, is 8.5 centimeters.[7] In the patients with unilateral dislocation in whom the shelf operation produced good anatomical and functional results, the Y coordinate for the hip with a surgically created shelf measured the same as, or less than 1.2 centimeters more than, the Y coordinate for the normal hip. On the other hand, in the patients with unilateral dislocation who had poor functional results from the shelf operation, the Y coordinate of the shelved hip was from 1 centimeter to as much as 5 centimeters larger than the Y coordinate of the normal hip, and the greater this difference, the more pronounced was the limp (Figs. 1 and 2).

In the patients in whom the limp disappeared after the shelf operation, it was noted that the femoral head was centrally placed in the primary acetabulum at the time the shelf was constructed, and remained there during and after the period of immobilization.[5] The shelf in such a hip usually became smaller after a period of walking, and in some

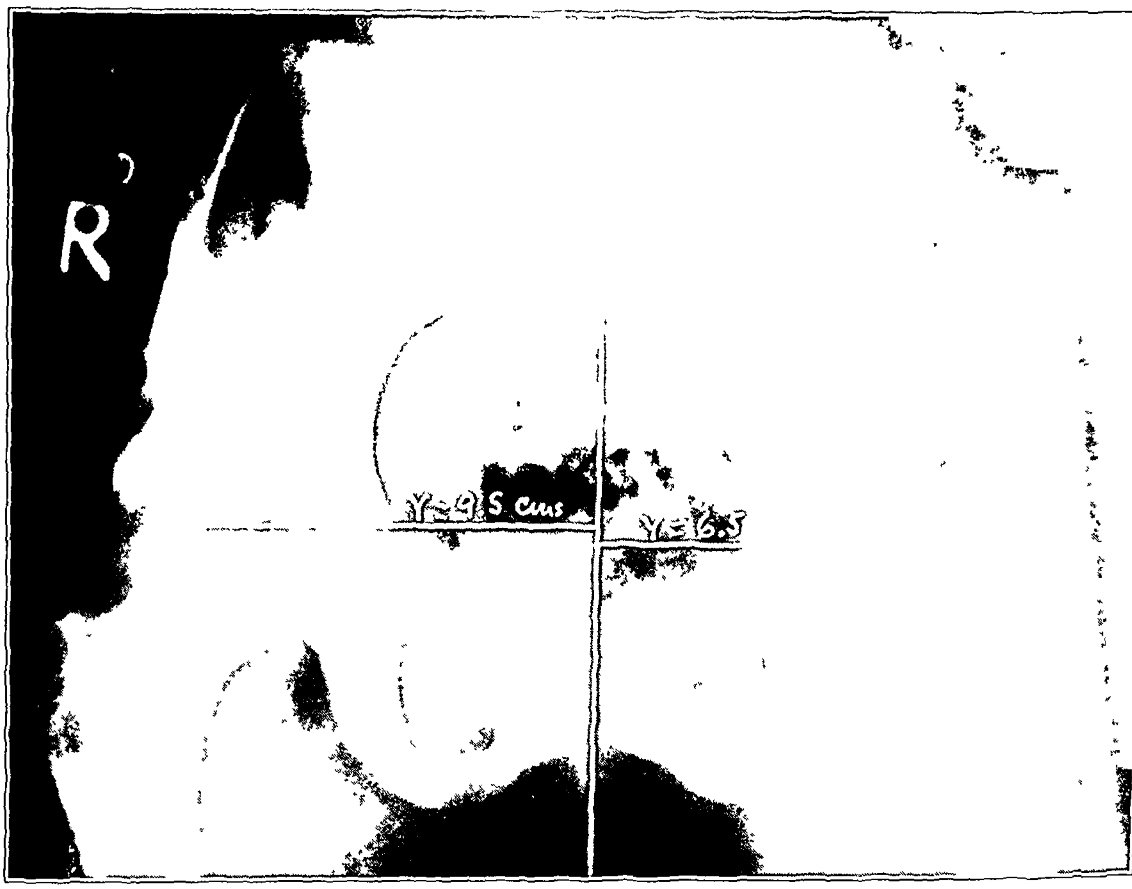

FIG. 1

J. R., No. 38-15836. Girl with congenital dislocation of right hip. Shelf operation done when patient was seven years of age. Roentgenograms taken at eleven years of age show that the Y coordinate of the right hip measures 9.5 centimeters, whereas the Y coordinate of the left hip measures 6.5 centimeters. Consequently, the Trendelenburg sign is positive on the right and negative on the left. Notice that the entire right iliac bone is deformed.

FIG. 2

H. M., No. 38–15654. Girl with bilateral dislocation of hip, treated by bilateral closed reduction at three and a half years of age. Shelf operation performed on left hip at five years of age, because of redislocation. Roentgenograms taken at seven years show that the Y coordinate measures 7.3 centimeters for the right hip and 8.5 centimeters for the left hip. Trendelenburg sign is negative on the right, positive on the left.

cases it seemed to disappear completely (Fig. 3-D). The Trendelenburg sign became negative within from two to six months after the patient began to walk following the shelf operation.

In most cases, however, the shelf was built at the upper end of a sloping acetabular roof; and, when the patient started to walk, the femoral head came under the shelf, at a somewhat higher level than the normal hip and slightly more separated from the line of gravity. Thus the acetabular cavity, with its roof widened by the shelf, provides for the femoral head a fulcrum which is mechanically defective, because it is too far separated from the line of gravity.

The passive support offered by a well-built shelf is not enough to maintain the central position of the femoral head in the acetabular cavity. The active stabilizing action on the hip joint is provided by the hip muscles, mainly the gluteus medius. If this muscle has been weakened by surgery, followed by a period of immobilization in a cast, the femoral head will not remain well centralized in the acetabular cavity when the patient begins to walk, in spite of a well-built shelf. The capsule and ligaments of the hip joint must also become shorter to secure complete reduction of the femoral head.

The hip muscles are not strong enough to neutralize the rotatory effect produced by gravity upon a hip with the femoral head subluxated under the shelf, and consequently the Trendelenburg sign becomes positive. In the hips where this sign remained positive for more than six months, both functional and anatomical results became permanently poor. Due to the inability of the glutei to stabilize the new joint, the pelvis tilts toward the opposite side with every step and the femoral head slips somewhat upward but mainly

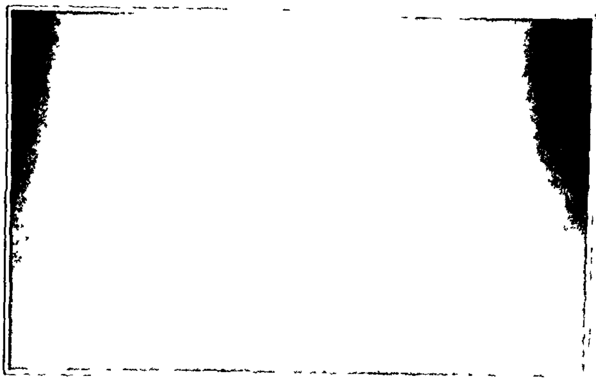

Fig. 3-A

Fig. 3-B

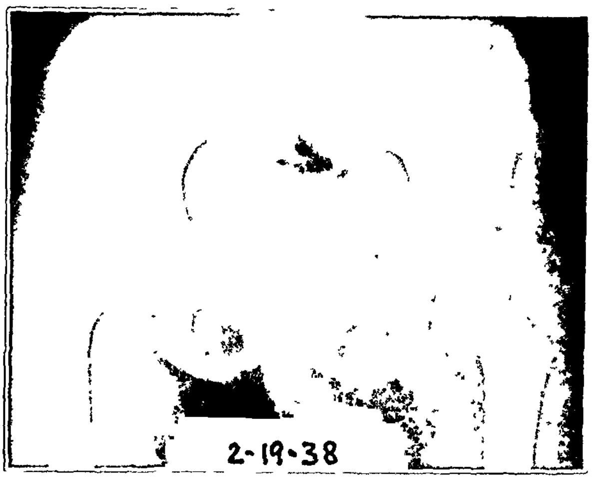

Fig. 3-C

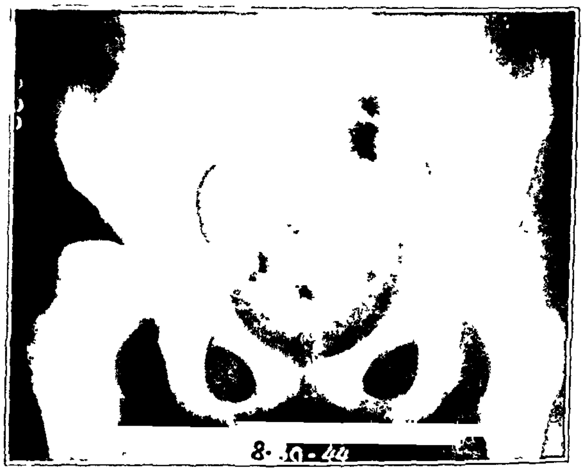

Fig. 3-D

B. B., No. 38-15173. Girl with bilateral dislocation of hips, treated by closed reduction.

Fig. 3-A: Subluxation of left hip, one month after removal of cast (Apr. 24, 1936).

Fig. 3-B: *Shelf operation performed on left; the femoral head is well centralized in the acetabular cavity.*

Fig. 3-C: One and one-half years after operation.

Fig. 3-D: Eight years after shelf operation. The shelf has disappeared, but the result is good. The right hip is subluxated. Trendelenburg sign is negative on the left and slightly positive on the right.

outward, where the shelf is less resistant. The bone of the shelf reacts to the intermittent pressure of the femoral head by forming new bone, and frequently the shelf not only becomes thicker but also wider in order to house the displaced femoral head. The center of motion of the hip becomes more and more separated from the line of gravity; and, therefore, the limp will persist, even if the glutei become stronger (Fig. 4-C).

The best functional results are seen, not in the hips with a stouter shelf, but in those where the femoral head is close to the line of gravity. In patients with bilateral shelf operations, it is frequently seen that the Trendelenburg sign and the limp are more marked on the side where the femoral head is farther from the line of gravity, even if the shelf is well developed, than on the side where the femoral head is closer to the line of gravity, even though the shelf may be atrophic or fragmented (Fig. 5). The aim of treatment for hip dislocation, therefore, is not the construction of a big shelf, but the exact centralization of the femoral head in the acetabular cavity during and after the period of immobilization. For these reasons careful surgery is essential, avoiding damage to the muscles. When the cast has been removed after the shelf operation, a period of controlled functional treatment with the abduction bar is indicated, as used by the author in the after-treatment of closed reduction.[4]

To improve the action of the gluteus medius it has been suggested that the greater

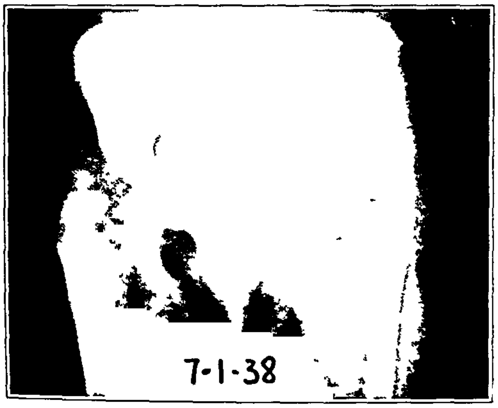

Fig. 4-A

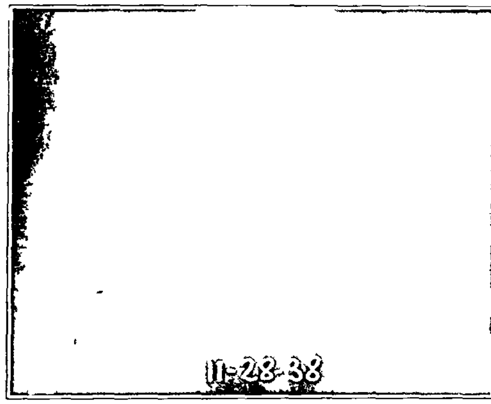

Fig 4-B

Fig 4-C

Fig 4-D

M. M , No 38–15832. Girl with congenital dislocation of right hip treated by closed reduction at the age of twenty-one months

Fig 4-A. Shows redislocation, three months after removal of cast

Fig 4-B: Four months after shelf operation The femoral head is not well centered in the primary acetabulum.

Fig 4-C· A year and nine months after the shelf operation (Apr 10, 1940). The femoral head became displaced away from the line of gravity and the shelf reacted by becoming thicker and wider.

Fig 4-D Six and one-half years after shelf operation The Y coordinate measures 9.5 centimeters for the right hip and 7 centimeters for the left hip Trendelenburg sign is positive on the right

trochanter, together with its muscle insertions, be transposed downward over the lateral aspect of the shaft of the femur. In five hips of the present series, this procedure was followed, in addition to the shelf operation. In four of these hips the femoral head was reduced into the primary acetabulum, and the functional result was poor in all (two of Group 4 and two of Group 6). The other hip was dislocated posteriorly and the shelf operation was performed with the femoral head in a secondary acetabulum; the functional result was bad (Group 6). In neither hip could benefit be attributed to the transposition of the greater trochanter. When bone shortening and bone lengthening are performed for equalization of the extremities, the muscles adapt themselves to the new situation and become structurally shortened or lengthened, corresponding to the approach or separation of the points of origin and insertion. Steindler has stated that: "The contracted muscle in adapting itself readily to the new mechanical arrangement becomes a new complete and rational mechanical unit". The transposition of the greater trochanter is thus worthless and unnecessary.

It is easy to understand why the limp persisted in all patients in whom the shelf was

built over the femoral head in a secondary acetabulum or in no acetabulum. In these patients the center of motion of the dislocated hip joint was already beyond the normal distance from the line of gravity. This distance is certainly not shortened by the creation of a shelf.[1] The force of the gluteus medius is not strong enough to oppose the great rotatory effect acting over this displaced center of motion; and, consequently, the Trendelenburg sign will remain positive and the patient will continue to limp.

If the hip is dislocated posteriorly, we have to consider not only the rotatory effect upon the hip joint in the frontal plane, but also in the sagittal plane. The line of gravity in the sagittal plane normally passes through or slightly behind the hip joint. If the center of motion of the hip is displaced backward, the pelvis will tilt not only to the opposite side, but also forward. Under these conditions a shelf will be a mechanical failure, unless the femoral head can be reduced into the primary acetabulum, or at least be transposed anteriorly, thus neutralizing the forward tilt of the pelvis.

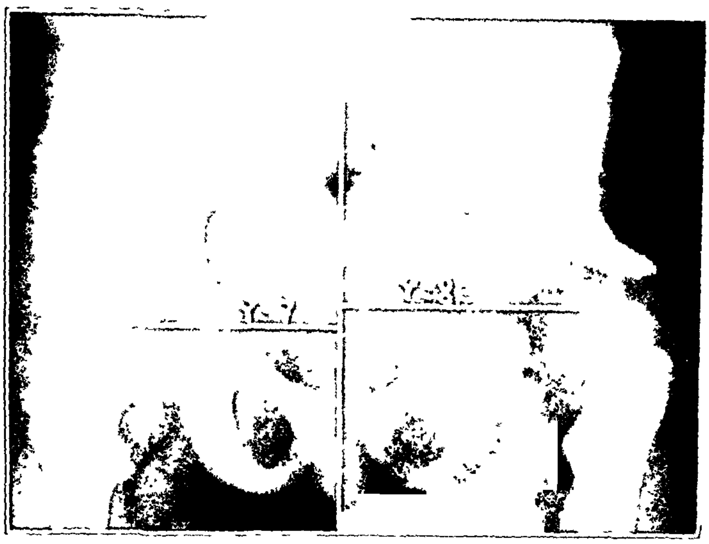

FIG. 5

J. R., No. 38-10866. Roentgenogram of an eight-year-old girl with congenital dislocation of the hips, who had been treated by bilateral shelf operation at three years of age. The Y coordinate of the right hip is 7 centimeters; that of the left hip is 8.3 centimeters. The Trendelenburg sign is negative on the right, although the shelf is fragmented, because the femoral head is well centralized in the acetabular cavity and is close to the line of gravity. On the left the Trendelenburg sign is positive, in spite of a stout shelf, because the femoral head is away from the line of gravity.

INDICATIONS FOR THE SHELF OPERATION

In young children with congenital dislocation of the hip treated by closed reduction, prolonged and controlled functional after-treatment by means of the abduction bar has shown that a shelf is not necessary to maintain reduction of the femoral head. The development of the hip muscles before the patient is allowed to walk, and the prolonged positioning of the limb in abduction and inward rotation [4] have been sufficient to maintain the femoral head well centralized in the acetabular cavity. When this has been accomplished, the acetabular roof develops well.

In children over four years of age, if the closed reduction has failed and an open reduction has been carried out successfully, the construction of a shelf may be indicated in case the acetabulum is very shallow. One must not rely too much on the shelf. To secure a good result, it is essential to place the lower extremity in a position of abduction and inward rotation for three months in a cast, followed by prolonged and well-directed functional after-treatment.

Symptoms are absent or very mild in patients with congenital subluxation until adult life; then pain, more or less severe on walking, and a mild limp usually develop. The pain is usually well controlled by a shelf operation. By giving a bony support to the femoral head, the strain on the capsule and ligaments of the hip joint is relieved; and, consequently, the pain disappears, although the limp may persist. A shelf operation is thus indicated in patients with congenital subluxations after the development of pain on walking and a slight limp. The operation is also indicated in a patient with congenital dislocation of a hip, reduced in childhood, which becomes subluxated after puberty.

When the femoral head cannot be reduced into the primary acetabulum, the hip will always be mechanically defective, in spite of a shelf operation. Although the telescoping is abolished and the pain on walking diminishes for a certain period of time, pain and

limitation of motion frequently appear a few years after the shelf operation has been performed. Osteo-arthritis of the hip usually accounts for these symptoms. It is the experience of this Clinic that, in patients with irreducible dislocations, a well-performed Schanz osteotomy, as outlined by Milch, gives good functional results, because the direction of the weight-bearing stresses is changed and approaches the line of gravity, thus improving the stability of the pelvis. In adult patients with complete, irreducible dislocation of the hip—unilateral or bilateral—a Schanz osteotomy is mechanically a better operation than a shelf operation.

It must be noted that, if a Schanz osteotomy is performed in a child, the angle of osteotomy will slowly diminish and the femur may even become completely straight as the patient grows. Young patients with irreducible dislocated hips thus present a difficult problem. The limp is their only symptom, and this will not disappear after a shelf operation. If a Schanz osteotomy is performed, it will probably have to be repeated when the patient reaches adult age. Even without treatment, in the patients with irreducible anterior dislocations a secondary acetabulum develops, and usually the femoral head does not dislocate farther upward. We believe that these patients should be observed periodically until puberty and, if pain occurs at that time, a Schanz osteotomy should be performed. Young patients with irreducible posterior dislocations are better treated by a Schanz osteotomy, even before puberty, if the femoral head tends to become more and more displaced upward and backward under the iliac wing. If the angle of the osteotomy diminishes, a second operation may be performed after puberty. The anterior transposition of the femoral head is a laborious and traumatizing procedure, which cannot always be accomplished.

Observation of this series indicates that the results obtained by shelf operations after forceful reduction of the hip, with or without preoperative traction of the limb, are very poor.[8] Reaming or deepening of the acetabular cavity usually results in stiffness of the hip joint.

SUMMARY

Dislocated or subluxated hips became more stable after a shelf operation, and the telescoping disappeared. However, the Trendelenburg sign remained positive, and consequently the limp persisted in all the patients with hip dislocation, treated by the shelf operation with the femoral head in a secondary acetabulum or in no acetabulum. When the shelf was built over the femoral head, after it had been placed in the primary acetabulum, the Trendelenburg sign became negative in only 18 per cent. of the patients. This sign remained positive in many patients, because, after the shelf operation, the femoral head usually became displaced under the shelf away from the line of gravity of the body. When the patient started to walk, the hip muscles were impotent to neutralize the increased rotatory effect produced by gravity upon this displaced center of motion. The Trendelenburg sign became negative only when the femoral head remained well centralized in the primary acetabulum. In these patients the shelf became smaller or even disappeared. On the other hand, in the patients whose Trendelenburg sign continued to be positive, the shelf became thicker and wider, due to the intermittent pressure of the displaced femoral head against the shelf.

From these observations, it was concluded that the aim of treatment for dislocation of the hip is not the construction of a big shelf, but the exact and permanent centralization of the femoral head in the acetabular cavity. The shelf alone is unable to accomplish this. The hip muscles must become strong and the capsule and ligaments of the hip joint must shrink to make secure the complete reduction of the femoral head. This may be accomplished in young patients by prolonged and well-directed functional after-treatment following reduction, with or without a concomitant shelf operation.

In the author's experience, the two main indications for the shelf operation are as follows: (1) In children over four years of age with congenital dislocation, reduced by

the open method, a shelf may be created if the acetabulum is shallow; and (2) in patients with congenital or paralytic subluxation, or with subluxation of an old reduced congenital dislocation, the shelf operation is indicated when pain of static origin and a limp appear, usually after puberty. When reduction of the femoral head cannot be maintained in the primary acetabulum, the shelved hip will always be mechanically defective; a Schanz osteotomy is indicated in these cases.

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EARLY SECONDARY CLOSURE FOLLOWING SAUCERIZATION FOR CHRONIC INFECTION OF BONE

A Preliminary Report

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The widely accepted Orr-Trueta, or closed-plaster, technique has been until recently the method of choice in treating chronic exogenous osteomyelitis. There are, however, several undesirable factors associated with this method of treatment,—namely: (1) the prolonged period of healing; (2) the stench of the soiled cast and consequent lowering of the patient's morale; (3) the presence of avascular scar tissue in the healed wound; and (4) the loss of essential body fluids.

The first and third points are of the most significance in the treatment of war casualties. Bed space in Army general hospitals has been limited, and consequently any form of treatment which will decrease a patient's period of hospitalization is desirable. In many cases, there has been extensive loss of bone, which will necessitate bone-grafting at a later date. To ensure the optimum opportunity for the eventual success of such grafting procedures, one must have a soft-tissue bed which is as vascular and as free from scar tissue as possible. This is not afforded by the closed-plaster method.

Stimulated by the success of Kelly and Burgess of the Fifth Service Command in covering depressed, granulating, post-saucerization wounds with split-thickness skin grafts, the author began to experiment with early secondary closure. When a granulating, saucerized depression is covered with a split-thickness skin graft, a lined depression results. This depression should be obliterated and the edges of the normal skin should be approximated, particularly if further bone surgery is required. It then seemed logical, in regions where it was possible, to circumvent this intermediate step and secondarily to close the skin edges of the saucerized wound. If this procedure should be successful, the period of hospitalization would be diminished by months and perhaps by years. It was assumed that these "dirty" wounds could be closed as satisfactorily as they could be grafted.

This method of treatment is contrary to many accepted principles of good surgery. A septic wound is completely closed, without drainage. The assistance derived from the use of penicillin and the sulfonamides has been great, but it is almost impossible to evaluate accurately the relative importance of these agents and of the surgical procedure. One may hazard a guess, however, that the method would have failed had penicillin and the sulfonamides not been available.

The general condition of a patient with a chronic infection of the bone should be evaluated upon admission to the hospital. Before a surgical procedure is carried out, the patient's hemoglobin, total proteins, and albumin-globulin ratio must be approximately normal. Beginning forty-eight hours before the operation, the patient should be given 25,000 units of penicillin systemically every three hours, day and night; and one and one-half grams of sulfadiazine by mouth every six hours, day and night. On the third day he is taken to the operating room. A pneumatic tourniquet is applied, if possible, to the extremity. Material for cultures is taken from the sinus, which is then injected with equal parts of methylene blue and hydrogen peroxide, in order that the extent of the infected cavity may be delineated. The entire dyed area is widely and meticulously saucerized; great care should be exerted to remove all scar tissue and any overhanging ledges of bone or of soft tissue. The wound is "frosted" with sulfanilamide crystals. One or more lengths of soft rubber tubing, with a lumen of one-eighth of an inch, are inserted into the depth of the wound. The tubing is transfixed to the skin by a catgut

suture. The wound is then packed *firmly*, but not tightly, with fine-meshed plain gauze packing, which has a thread count of sixty to the inch. Muslin which has been impregnated with petrolatum is used to cover the packed wound, and the tubing emerges through openings in the muslin. The extremity is encased in plaster, and the tubes are brought through the plaster to the surface. The antibiotics are continued as before operation. Penicillin (one cubic centimeter containing 750 units), in quantities of from five to fifteen cubic centimeters, is injected into the tubes twice daily.

On the eighth day after saucerization, a window is cut in the cast or the cast is bivalved. The packing and tubing are removed. At this time the decision is made as to whether the wound will be treated by skin-grafting or by secondary closure.

The author has found that saucerized wounds on the arm, forearm, thigh, buttocks, or shoulders lend themselves to satisfactory secondary closure, whereas those on the leg or foot, or in the region of the elbow or knee, can be treated more satisfactorily by skin-grafting. The primary prerequisite of a successful secondary closure is the availability of adequate soft tissue which can be mobilized sufficiently to obliterate the excavation. The procedure chosen should be carried out, ideally, on the ninth or tenth day after saucerization.

Packing which has been soaked in half-strength Dakin's solution is inserted in the wound after the first dressing. The packing is changed daily, and is finally removed in the operating room.

For secondary closure, the skin surrounding the wound is prepared in the routine manner. No chemicals are allowed to enter the wound. The skin edges and the granulating walls of the cavity are resected; bleeding is controlled with hot saline packs. The wound surfaces are "frosted" with sulfanilamide crystals. An effort is made to obliterate all dead space, but this is frequently impossible, as the soft tissues cannot be mobilized adequately to fill the dead space in the underlying bone. Layers of muscle and of fascia are closed with interrupted sutures of fine chromic catgut. The skin is widely undercut to allow closure without tension on the edges. Great care must be taken to obliterate any subcutaneous dead space which may be present. The persistence of such a space is the commonest cause of incomplete healing and of continued serosanguineous discharge. The skin may be closed with absorbable or non-absorbable sutures, at the discretion of the operator.

After secondary closure, the antibiotics are resumed, in doses similar to those given before and after saucerization. This medication should be continued for at least one week after operation, or longer if local conditions warrant.

The first postoperative dressing is done on the eighth day, and the degree of healing can be evaluated at this time. To be considered "completely healed", the wound must be dry, and must be without drainage, subcutaneous dead space, or skin ulceration. For the purposes of this report, a wound was not considered "completely healed" unless it had remained so for thirty days after the secondary closure.

The results in the first fifty cases of secondary closure of post-saucerization wounds, performed at Nichols General Hospital, are reported. It will be noted that in a number of cases the period between saucerization and secondary closure was prolonged. The procedure described in this paper was not instituted until early in March 1945. At that time, many wounds which had been saucerized several months before and had been treated by the closed-plaster method were still unhealed. These wounds were closed secondarily.

Of the fifty cases, thirty-five, or 70 per cent., healed primarily; fifteen, or 30 per cent., were classified as incompletely healed. Eight of the fifteen were healed one month after secondary closure. Therefore, one month after secondary closure, forty-three, or 86 per cent. of all the closures, were completely healed. Not one of the fifty cases could be classified as a complete failure. The poorest case was estimated to have 35 per cent.

TABLE I

RESULTS OBTAINED FROM SECONDARY CLOSURE FOLLOWING SAUCERIZATION

Location	Total Number of Cases	Healed (*Number*)	Healed (*Per cent.*)	Incompletely Healed (*Number*)	Incompletely Healed (*Per cent.*)
Shoulder	2	2	100	0	0
Upper arm	10	10	100	0	0
Forearm	9	7	77	2	23
Thigh	16	12	75	4	25
Leg	1	0	0	1	100
Foot and ankle	1	0	0	1	100
Joint areas	7	1	14	6	86
Pelvis	4	3	75	1	25
Totals	50	35	70	15	30

healing. A number of cases which had been classified as incompletely healed were secondarily closed a second time, and complete healing occurred eventually.

There is considerable variation in the time which elapsed between saucerization and secondary closure. The earliest closure which was attempted after saucerization was done in seven days, the latest in 126 days. Both resulted in complete healing. The average number of days which elapsed between saucerization and secondary closure was 27.6. In nineteen, or 38 per cent., of the fifty cases, secondary closure was performed ten days or less after saucerization; in thirty-one, or 62 per cent., closure was delayed for more than ten days. Of the nineteen wounds which were closed in ten days or less, nine, or 48 per cent., were healed completely at the time of the first dressing; ten, or 52 per cent., were considered unhealed. Twenty-six, or 84 per cent., of the wounds closed in something over ten days after saucerization healed primarily; five, or 16 per cent., were classified as unhealed. When we consider that, in the cases of very early secondary closure, we are attempting closure of grossly infected wounds, while in the cases of late secondary closure we are practising excision of chronic granulating wounds, the comparison is not too striking. The objectives of early closure are to produce healing with a minimum of fibrosis and to decrease appreciably the period of hospitalization. A delay of 126 days between saucerization and secondary closure certainly fails to accomplish either objective. The risk of failure in early secondary closure is obviously greater than that encountered in cases where closure has been postponed unduly. However, the risk is compensated for by the relatively high percentage of satisfactory results and the great saving in hospital days.

The anatomical distribution of the cases and the percentages of healing and incomplete healing are shown in Table I. The percentage of complete healing in regions proximal to and involving the joints was low, but of the seven cases in which secondary closure was attempted in these areas, all but one are now completely healed. Further surgery will be required in this case.

No extensive bacteriological studies were instituted. Material for culture was taken from the existing sinus or sinuses at the time of saucerization. Thirty-five per cent. of the wounds contained hemolytic *Staphylococcus aureus*. Most of the wounds had a superimposed *Bacillus proteus* infection. Culture material was not taken from the wounds at the time of secondary closure.

INTERTROCHANTERIC FRACTURES AND FRACTURES OF THE NECK OF THE FEMUR

A Guide and a Method of Procedure for Accurate Placement of a Nail

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The need for a simple, accurate, and practical guide for nailing hips is obvious. A review of the literature reveals many different devices for this purpose, with most of which the orthopaedic surgeon is familiar.

The guide described here removes the element of luck and affords mechanical efficiency in accurately nailing all types of fractures of the femoral neck and intertrochanteric fractures. When properly applied to the femur, it will permit the accurate introduction of the wire and nail at the desired angle in both the anteroposterior and lateral planes.

The guide consists of a block of stainless steel (18–8), diagonally divided and held in one piece with two dowel pins and one set screw (Figs. 1, 2, and 3). This division permits proper cleaning after use. The block is roughly two inches wide, three-quarters of an inch thick, and two and one-half inches long. There are three flat surfaces, one rounded surface, and one surface tunneled in V shape, which contains fixation prick pins to be applied to the lateral surface of the femur. This V-shaped surface is notched for the purpose of getting accurate alignment on the lateral roentgenograms. At the center of one notch there is a hardened drill bushing for pin transmission. On the opposite side of the V-shaped surface there is a drill hole, three-sixteenths of an inch in diameter and seven-eighths of an inch deep, which receives the vertical rod, adjustment screw, and clamp assembly which hold the block firmly against the lateral femoral surface. The rounded surface has twelve drill holes, three-thirty-seconds of an inch in diameter, placed at angles of 20 degrees, 30 degrees, 45 degrees, and 55 degrees. They all converge to a common center at the apex and pass through the drill bushing (Fig. 2, *b*). The holes are set three in line vertically and four in line horizontally, and through them pass four V-shaped notches, which afford contrast on the roentgenogram and permit proper alignment. The block may be used for the right or left side simply by turning it over. It is held in position against the femur by a clamp assembly (Figs. 4 and 5), which consists of the following parts: two arms, one yoke, and two adjustment screws,—one vertical and one horizontal.

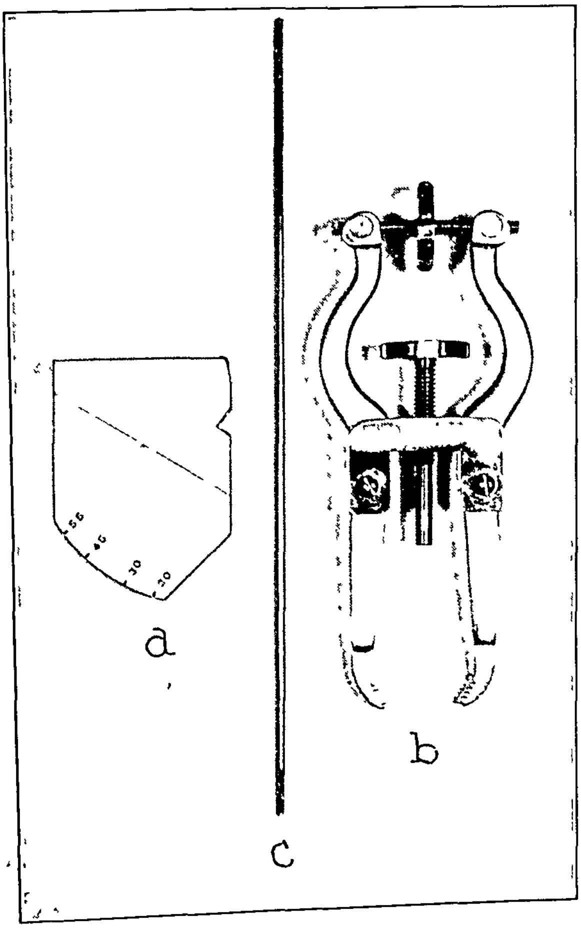


Fig. 1

a: Shows the block, sighting V at drill bushing, diagonal line where block can be separated, and four small V's at angles of 20, 30, 45, and 55 degrees.

b: Shows the clamp assembly.

c: Shows a Steinmann pin.

The application of this guide is rapid, safe, and simple. The steps in the procedure are as follows:

1. With the patient under anaesthesia, the fracture is reduced and the limb is fixed in full internal rotation to the foot-piece of the orthopaedic operating table. The rotation removes the normal anterior inclination of the femoral neck.

2. The reduction is checked by means of two portable roentgenographic machines, placed for anteroposterior and lateral views.

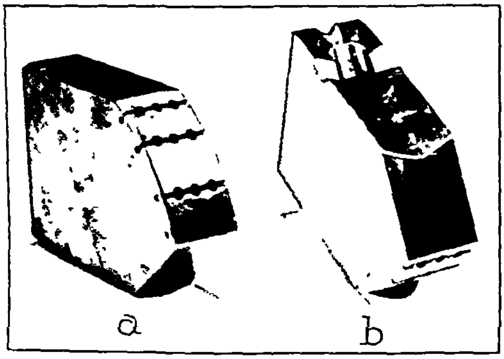


FIG. 2

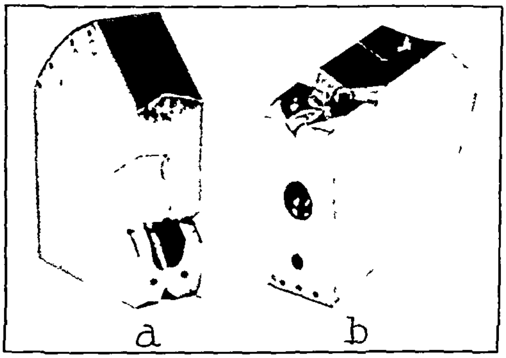


FIG. 3

Fig. 2, *a*: Shows the curved surface of the block, the small sighting V's, twelve drill holes, and the three-sixteenth-inch drill hole for the vertical rod of the clamp. *b*: Shows the prick pins, center drill bushing, the lateral and anteroposterior sighting V's, and the V-shaped surface.

Fig. 3, *a*: Shows a dowel pin, sighting V, and prick pins. *b* Shows two sighting V's, three prick pins, the drill bushing, and set screw to hold block in one piece

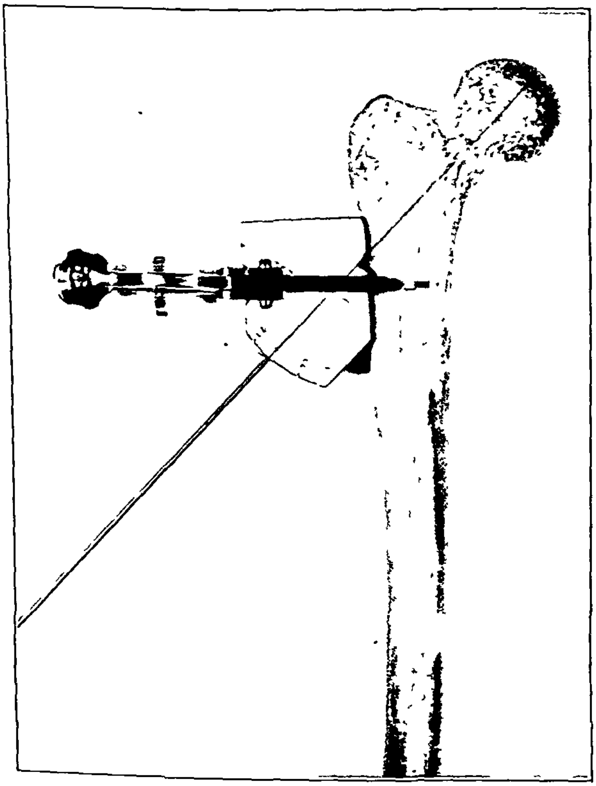


FIG. 4

Shows the application of the guide to the femur in the anteroposterior plane. Guide wire is in the center 45-degree hole, with a thread extended over the femoral head and neck.

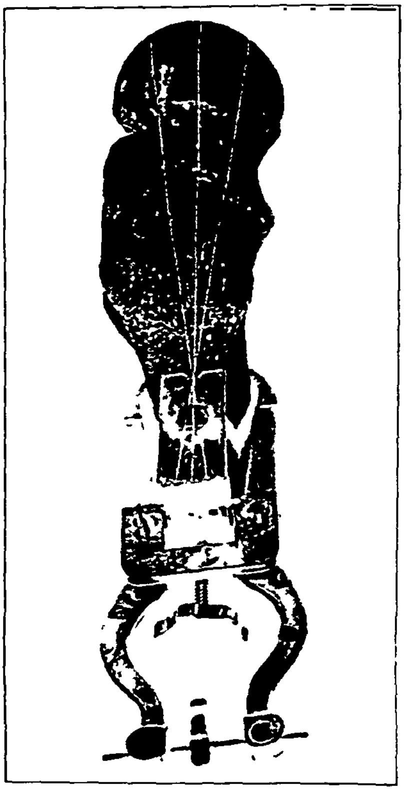


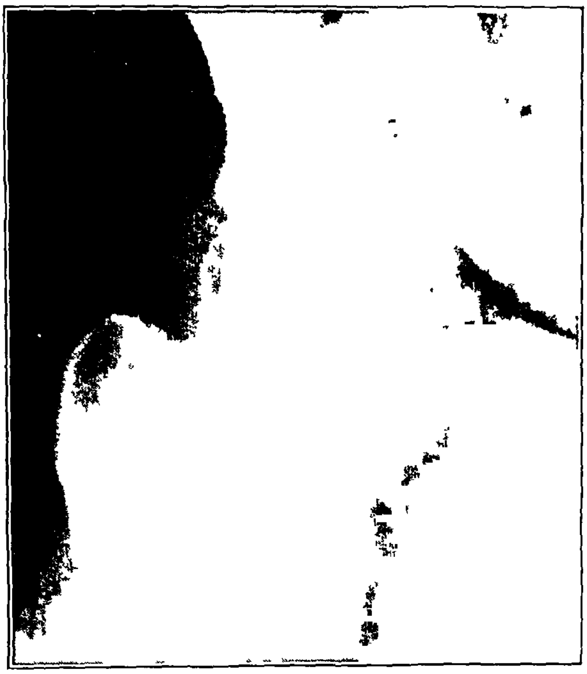
FIG 5

Shows guide applied to femur in superior-inferior plane, with three threads to show angles of center, upper, and lower holes in the block.

3. If the reduction is found to be satisfactory (Figs. 6-A and 6-B), the operative site is prepared.

4. An incision, three and one-half to four inches long, is made along the lateral border of the femur, extending distally from the greater trochanter. The femur is exposed.

5. The block is placed in the clamp assembly and the serrated clamps are applied to the upper shaft of the femur (Figs. 6-C and 6-D); the upper surface of the block should be within one-half inch of the lower margin of the greater trochanter. The guide block is screwed firmly against the outer cortex of the shaft of the femur; it should be about midway



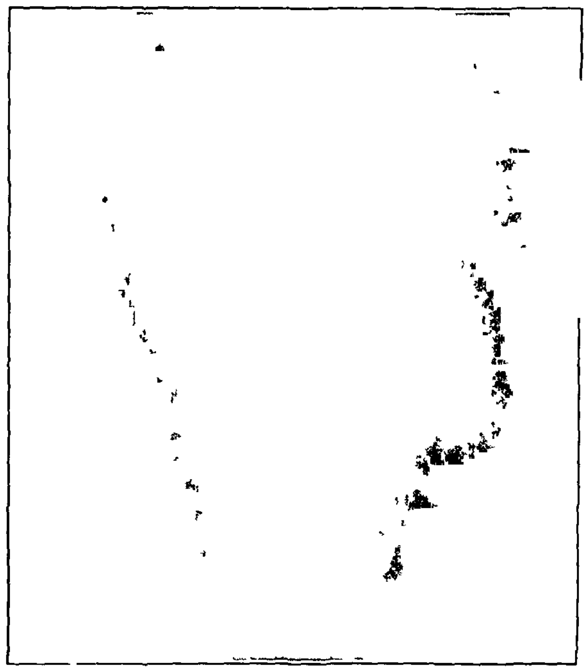


FIG. 6-A FIG. 6-B

Anteroposterior and lateral roentgenograms, showing fracture of the right femoral neck, after reduction.

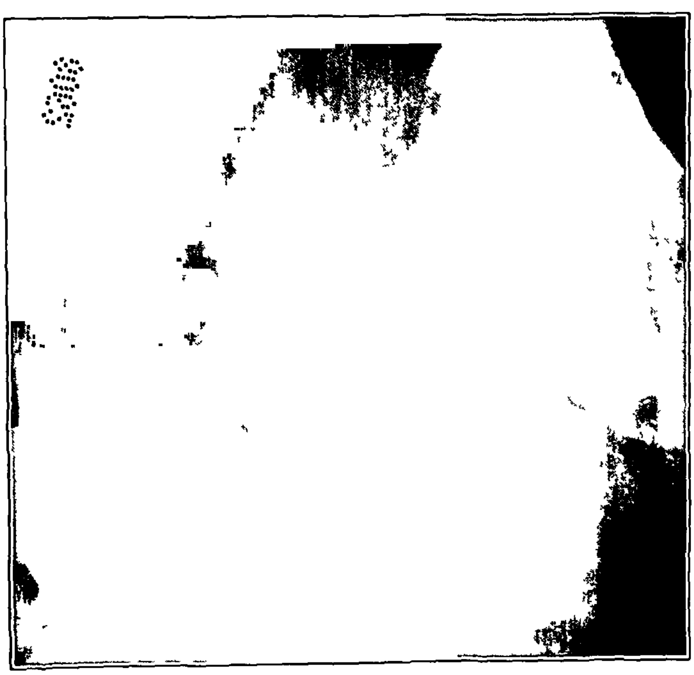


FIG. 6-C

Anteroposterior view shows the guide and pin applied to the femoral shaft.

FIG. 6-D

Lateral view partially shows the guide applied to the femur.

between the anterior and posterior surfaces of the shaft and level to the naked eye on its flat upper surface,—that is, parallel to the flat anterior surface of the femoral shaft.

6. A nail guide pin is placed in the center hole of the 45-degree angle

7. Anteroposterior and lateral films are taken so as to include in the film the guide with the pin.

Fig 6-E

Fig 6-F

Anteroposterior and lateral roentgenograms, showing the guide pin extending beyond the line of fracture

Fig 6-G

Anteroposterior view of nail in position selected, at conclusion.

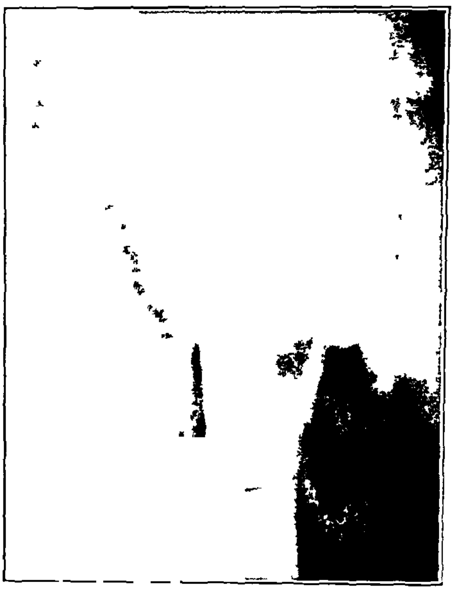


Fig 6-H

Lateral view of nail, with minimum rotation of femoral head, at conclusion.

Fig 6-I
Anteroposterior view of fracture of the right femoral neck

Fig 6-J
Oblique view of fracture of the right femoral neck

8. A sight is taken along the pin and the grooved notches in the block on the anteroposterior and lateral films, and, with a straight edge on the film, a determination is made of the exact hole to be used to place the nail properly.

9. Using this hole, the guide pin is placed in a hand drill and inserted to the desired depth (Figs. 6-E and 6-F).

10. The block and clamp assembly are removed, but the pin is left in place

11. With a 0 333-inch cannulated drill over the wire, a hole is cut in the cortex of the femur to receive the cannulated nail. With a special ruler, the nail length can be estimated or calculated from the known width of the block (two inches) accurately enough for all practical purposes. The distortion is usually about one to four.

12. The nail is placed on the introducer and driven into the femoral neck (Figs. 6-G and 6-H).

13. The foot fixation to the table is released, the fracture is impacted, and final anteroposterior and lateral films are made.

14. The guide pin is removed and the wound is closed in layers.

The following illustrative case is taken from a series of over twenty-five cases in which the author has used this procedure:

A K., No 8062, a married housewife, aged fifty-six, slipped on an icy doorstep and fell on her right hip one hour before admission to the Strong Memorial Hospital on December 1, 1945 She had instantaneous pain in the right hip, with numbness and weakness of the right leg and inability to walk

On physical examination, the right leg was found to be shortened and in a position of external rotation There was tenderness over the greater trochanter Attempts at motion were painful The general physical examination was otherwise not remarkable Roentgenograms showed a fracture of the right femoral neck (Figs 6-I and 6-J) The patient was a known diabetic, whose disease was regulated with insulin

The patient was subjected to the procedure outlined, and the results are shown in Figures 6-A to 6-J, inclusive The postoperative course has been uneventful to date.

CONCLUSIONS

It is not always essential to use a mechanical device for nailing intertrochanteric fractures and fractures of the neck of the femur, but with such a method the nail may be placed in the desired position with certainty.

This device eliminates the need for fluoroscopy, which is not universally available nor entirely without risk. The results are frequently too indistinct to be of much help in large or obese patients, and biplane observation is not possible.

This guide helps eliminate improper placing of the nail at the time of operation, and reduces the time required for nailing the hip. It also reduces the cost for film, because fewer exposures are required, and it saves time for the roentgenologist.

By introducing only one guide wire, operative trauma at the site of injury is minimal The guide remains in a fixed position after it has been applied.

NOTE The author wishes to thank R Plato Schwartz, M.D., for his valuable suggestions, and Dr. Rachel Rice for her assistance

A SIMPLIFICATION OF BANKART'S CAPSULORRHAPHY FOR RECURRENT DISLOCATION OF THE SHOULDER

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The anterior capsulorrhaphy of Bankart has proved to be a most satisfactory operative procedure for recurrent dislocation of the shoulder, according to the author's observations. Its chief disadvantage is the technical difficulty encountered in carrying out the procedure as described by Bankart,—namely, suturing the humeral portion of the shoulder capsule to the rim of the glenoid and securing satisfactory fixation of soft tissue to bone. By the use of a stainless-steel staple, made from sixteenth-inch Kirschner wire, a special instrument for the insertion of this staple, and a special retractor (Fig. 1), the technical difficulties of the operative procedure have been overcome. The coracoid process need not be removed and it is only necessary to section the inferior half of the tendinous insertion of the subscapularis for adequate exposure. The operative time is practically cut in half, and the associated operative trauma is similarly reduced. In fact, one patient was operated upon satisfactorily without either section of the subscapularis or opening of the joint capsule.

OPERATIVE TECHNIQUE

A five-inch incision is made, beginning just above the coracoid process and extending downward between the borders of the deltoid and the pectoralis major. The cephalic vein is located and is retracted laterally with the deltoid. By dissection of the muscle plane, the deltoid and the pectoralis major are separated and retracted. The coracoid process is located, and into it are inserted the short head of the biceps, the coracobrachialis, and the pectoralis minor. With the shoulder in external rotation, the cleavage plane between the lateral border of the short head of the biceps and the subscapularis is defined and dissected; the muscles attached to the coracoid process are retracted medially. The distal and inferior border of the subscapularis is separated by blunt dissection, and the gloved finger is passed along this border to the antero-inferior margin of the glenoid cavity; by blunt dissection with the finger, the muscular attachments of the subscapularis to the antero-inferior portion of the capsule are freed up to its tendinous insertion.

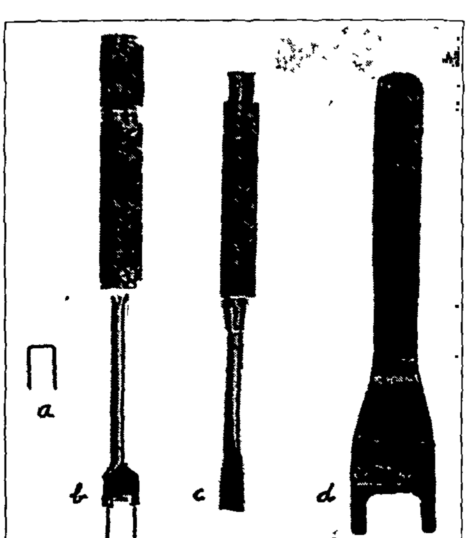

FIG. 1

The author's instruments for capsulorrhaphy. *a*: Staple. *b*: Staple holder, used for insertion and extraction. *c*: Staple set. *d*: Retractor.

Two No. 2 chromic sutures are then placed in the inferior half of the subscapularis tendon, and by retraction on these and by placing a large curved hemostat under the subscapularis, the tendinous insertion is defined and is slowly severed with a scalpel. This is a very important step in the procedure; unless the muscle fibers of the subscapularis are first dissected free from the capsule, as described, it is difficult to define the tendinous insertion and one may open into the joint capsule at a non-elective location. The only open tears the author has seen in the capsule have been those caused by the operator. When the inferior half of the subscapularis tendon has been divided, the special retractor is placed so that its bifurcated end rests on the neck of the glenoid cavity, and thus about one-half inch below the glenoid rim. This holds the subscapularis and the muscles attached to the coracoid process

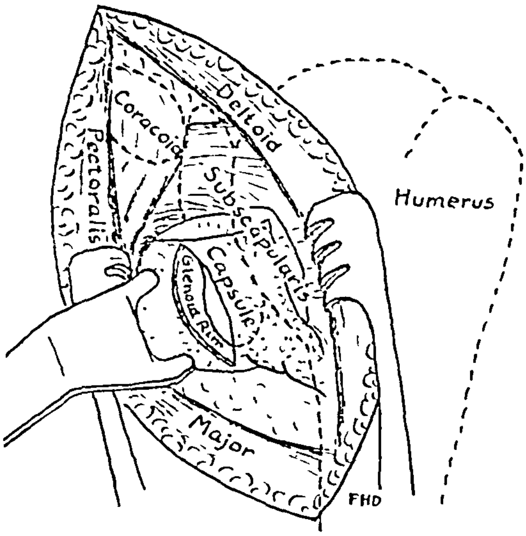

FIG. 2

Exposure of the antero-inferior glenoid margin and the capsular incision.

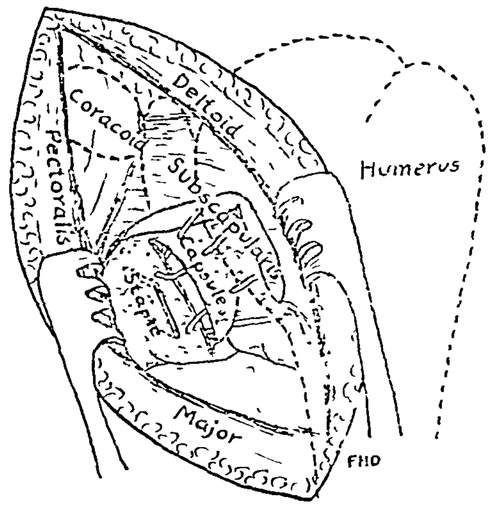

FIG. 3

Position of staple and technique of capsular repair.

behind the retractor, and exposes the antero-inferior portion of the glenoid rim, which is the location to be repaired.

The capsule is now entered by a one-inch incision, parallel to and just lateral to the glenoid rim (Fig. 2). The defect in the fibrocartilaginous attachment, and sometimes the bony edge of the glenoid cavity, is inspected. The glenoid rim is then roughened with a chisel or a curette. The scapular margin of the cut capsule is grasped at each corner with an Allis clamp and placed over the defect in the glenoid rim. This is fixed firmly in place by a stainless-steel staple, one-half inch in width and three-quarters of an inch in length; the staple is inserted with a special instrument and directed slightly toward the body and spine of the scapula. Before the staple is firmly set, its location and position are inspected through the capsular incision; if these are not correct, the staple can easily be withdrawn by the same instrument and reinserted (Fig. 3). The humeral edge of the capsular incision is now plicated over the scapular edge and fixed with two or three interrupted chromic sutures. This builds up and firmly fixes the glenoid rim, and it also shortens the antero-inferior portion of the joint capsule. The subscapularis tendon is resutured to its tendinous insertion with chromic sutures, and the remainder of the wound may be closed easily (Fig. 4).

FIG. 4

Postoperative roentgenogram, showing the staple in position.

POSTOPERATIVE TREATMENT

The arm is strapped to the side for two weeks, and an arm sling is worn for an additional week. Active exercises are then started, and are increased as recovery pro-

gresses. By the end of six weeks, as a rule, 90 degrees of active abduction can be obtained. It usually takes from eight to twelve weeks before the normal range of shoulder motion is restored.

RESULTS

The staple method of capsular fixation has been used in twenty-four cases. The first patient, a Fireman Third Class, aged twenty-one, was operated upon September 21, 1943, at the United States Naval Hospital, Mare Island, California, and returned to full duty in less than eight weeks. There has been no known recurrence in any case. A slight limitation of external rotation may persist, but this has never been a cause for complaint.

The end results and comparative results of the major portion of this series are reported by Myers.

The author has also fixed the capsule to the rim of the glenoid by means of two or three stainless-steel nails, according to the method of Toffelmier, and by the use of a vitallium screw; but he prefers the staple.

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EXPERIENCE WITH CAPSULORRHAPHY FOR RECURRENT DISLOCATION OF THE SHOULDER

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Experience in the Armed Forces during the past four years has increased our knowledge of recurrent dislocations of the shoulder, and has afforded an excellent opportunity to study, analyze, and evaluate this particular entity.

The shoulder joint is a ball-and-socket joint which is subjected to a greater range of motion than other anatomical joints. It is held in place by a capsule, which is supported by a musculotendinous cuff throughout its entire girdle, except on the inferior aspect. Neviaser's anatomical description reveals this defect, which has been a pertinent factor in the present series of cases. Eyre-Brook has found, from dissections of twenty-one shoulders, that the superior and inferior glenohumeral ligaments are usually of considerable size and strength; and that the anterior capsule is always attached to the lip of the glenoid cavity and never to the neck of the scapula. This has been demonstrated by injecting lipiodol into the shoulder joint. The opening of the subscapular bursa is well away from the rim of the glenoid cavity and, therefore, cannot be confused with capsular detachment. The glenoid cavity is small and shallow, and only one-fourth of the articular surface of the humeral head is in contact with it at any time. The periphery consists of a fibrocartilaginous ring,—the glenoidal labrum. It is triangular in shape with a base attached by a dense fibrous tissue to the bone of the glenoid rim; one surface is in contact with the articular cartilage of the humerus, and the other is in contact with the capsule. A shallow sulcus intervenes—the subscapular recess—which is crossed by superior, middle, and inferior glenohumeral ligaments. This reflected fold of the capsule, with the synovial membrane lining its inner surface, must not be mistaken for detachment of the capsule.

When sufficient trauma has been exerted, the head is forced anteriorly or inferiorly (subglenoid) over the vulnerable sector of the glenoid rim, since the remainder of the joint is supported by the intimate union of the tendons of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles, and joint opposition can no longer be maintained at this point. The capsule is detached, with the fibrocartilaginous ring, or the labrum is fractured, or both, by the impact of the head of the humerus. Not infrequently the head of the humerus itself sustains injury. This detachment of fibrocartilaginous tissue with associated fracture or damage is difficult to repair and defects persist, whereas capsular tears in ordinary dislocations heal promptly.

Watson-Jones states that two essential features have escaped general observation for many years. The first is injury to the glenoid fibrocartilage, which is not disclosed by routine exposure of the joint and can be displayed only by special dissection. The second is injury to the head of the humerus, which is not visible in routine roentgenograms and is shown only in special projections.

Consequently, this detachment of the capsule and labrum, its fracture, the defect in the posterolateral sector of the head of the humerus, and the resulting capsular laxity permit the head to slip easily over the glenoid rim while still remaining intracapsular. This explains the facility with which so many dislocations are reduced by patients themselves, and the frequency with which individuals complain that the joint, although not actually dislocated, has "slipped", "given way", or momentarily "locked".

Bost and Inman have described the pathological changes of erosion, fracture, and defect of the glenoid rim. Proof that the two injuries of the head and of the rim were sustained simultaneously, by the impact of one bone against the other, is seen in the accurate fitting of the posterior defect of the head with the defect of the anterior rim of the glenoid.

TABLE I

EVALUATION OF THIRTY-ONE CASES

Case No.	Patient	Age	Type of Dislocation	Treatment of Coracoid	Section of Sub-scapularis	Capsule Incision	Pathological Changes: Capsule	Pathological Changes: Labrum	Pathological Changes: Osteo-chondritis	Capsule Fixation	End Results: Limitation of Motion	End Results: Functional Defect	End Results: Disposition
1	W. M. K.	24	Anterior glenoid	Excision	Total	Parallel to rim	Redundant	Fractured	Rim	Suture	25% in all planes	35%	S
2	W. M. K.	24	Posterior luxation			Parallel to rim	Detached	Fractured		Suture	25% in all planes		
3	H. K. J.	28	Anterior glenoid	Excision	Total	Parallel to rim		Fractured	Glenoid	Suture	Sl. abd. and ext. rot.	None	LD
4	L. E. S.	21	Subglenoid	Excision	Total	Parallel to rim	Detached	Fractured	Glenoid fossa	Suture	Sl. abd. and ext. rot.	None	S
5	R. B.	23	Anterior and subglenoid	Excision	Total	Parallel to rim	Detached	Fractured, 2½ cm.	Defect of rim	Suture	20% in all planes	15%	LD
6	D. G. B.	27	Subglenoid	Excision	Total	Parallel to rim	Tear of supra-spinatus	Fractured		Suture	10% in all planes	15%	S
7	H. G. F.	26	Anterior and subglenoid	Excision	Partial	Parallel to rim	Detached	Fractured		Suture	Sl. ext. rot.	None	D
8	F. G. C.	31	Subglenoid	Left intact	Partial	Parallel to rim	Detached	Fractured		Staple	Sl. ext. rot.	None	LD
9	W. H. W.	19	Subglenoid	Excision	Partial	Parallel to rim	Detached	Fractured	Rim	Suture	Sl. ext. rot.	None	LD
10	D. C. C.	21	Anterior and subglenoid	Excision	Partial	Parallel to rim	Tear, detached	Fractured		Suture	Sl. ext. rot.	None	D
11	R. H.	36	Anterior and subglenoid	Excision	Partial	Parallel to rim	Detached	Fractured	Fossa	Suture	Sl. ext. rot.	None	D
12	G. B. B.	25	Anterior and subglenoid	Left intact	Partial	Parallel to rim	Detached	Fractured		Staple	Sl. ext. rot. and abd.	None	S
13	G. S.	26	Anterior and subglenoid	Excision	Total	Parallel to rim	Detached	Fractured	Defect of rim	Staple and suture	Sl. ext. rot.	None	LD
14	P. R.	24	Anterior and subglenoid	Left intact	Partial	None	Detached		Defect of rim	Staple	10% ext. rot. and abd.	10%	S
15	R. W. T.	40	Anterior and subglenoid	Excision	Total	Parallel to rim	Detached	Fractured	Arthritis of head	Two staples	30% in all planes	50%	S

16	R. E. H.	22	Anterior and subglenoid	Excision	Partial	Parallel to rim	Detached	Fractured		Suture	Sl. ext. rot.	None	D
17	W. E. T.	29	Anterior and subglenoid	Left intact	Partial	Parallel to rim	Detached			Staple	Very sl. ext. rot.	None	D
18	A. Y.	21	Anterior and subglenoid	Excision	Partial	Parallel to rim	Detached	Detached		Staple	Sl. ext. rot.	None	D
19	C. S. C.	26	Subglenoid	Excision	Partial	Parallel to rim	Detached	Fractured	Rim and fossa	Staple	10% ext. rot.	5%	S
20	A. S.	32	Anterior and subglenoid	Excision	Partial	Parallel to rim	Detached	Fractured		Staple and suture	10% abd. and ext. rot.	10%	S
21	A. R. G.	19	Anterior and subglenoid	Excision	Partial	Vertical to rim	Detached			Suture and staple	15% in all planes	20%	S
22	B. M.	22	Anterior and subglenoid	Excision	Partial	Parallel to rim	Tear of supra-spinatus	Fractured		Suture	Sl. ext. rot.	None	S
23	R. C. M.	32	Anterior and subglenoid	Excision	Partial	Parallel to rim	Detached	Fractured	Defect of rim and head	Suture	10% ext. rot.	None	S
24	R. E. S.	26	Subglenoid	Excision	Partial	Parallel to rim	Detached		Rim	Suture and staple	Sl. ext. rot.	None	S
25	S. C. S.	18	Subglenoid	Intact	Partial	Parallel to rim		Fractured		Staple	None	None	D
26	D. L. T.	32	Anterior and subglenoid	Intact	Partial	Parallel to rim	Redundant, detached			Suture and staple	35% in all planes	50%	S
27	L. D. B.	40	Anterior and subglenoid	Excision	Partial	Parallel to rim	Detached, redundant	Fractured	Defect of rim	Suture and staple	Sl. ext. rot.	None	D
28	C. A. F.	20	Subglenoid	Excision	Partial	Parallel to rim	Redundant, detached		Rim	Suture and staple	Sl. ext. rot.	None	D
29	C. R. P.	20	Posterior luxation			Parallel to rim	Detached	Fractured		Suture and staple	Sl. ext. rot.	None	D
30	G. R. S.	20	Posterior luxation			Parallel to rim		Detached	Labrum, rim	Suture and staple	Under treatment		
31	K. A. H.	19	Posterior luxation			Parallel to rim		Notched rim	Labrum	Suture and staple	Under treatment		
Summary:							Detached 84%	Fractured 73%	Present in 48%			None in 66% 15% in 23% 50% or more in 7%	

S = Surveyed from Service (41%; all but three could do limited duty)
LD = Limited duty (17%)
D = Discharged to full duty (38%)

This series represents about 50 per cent. of the cases of recurrent dislocation seen on the Orthopaedic Service of this Hospital. There were ten patients with recurrent dislocation after a Nicola operation, a tenosuspension operation, or both, who refused further surgery. The remainder of the cases were either E.P.T.E. (existing prior to enlistment) or the patients refused operation and were discharged from the Armed Forces by a Board of Medical Survey. No cases of recurrence following the Bankart operation were seen on this Service. Some authorities claim that dislocation will recur, if at all, within one year of operation. This has not been borne out by observations on this Service.

With these facts in mind, it was decided to use an approach and a procedure similar to those described by Bankart, in order to find a better solution to the problem.

OPERATIVE TECHNIQUE

An anterior incision is used, extending from the tip of the coracoid process distally for six inches along the depression or groove between the deltoid and the pectoralis major. A dissection of the muscle plane is made between the deltoid and pectoralis muscles, and the deltoid is retracted laterally with the cephalic vein. The cephalic vein is used as a guide to muscle dissection. The short head of the biceps and the coracobrachialis muscles are exposed and are freed along the lateral border. No dissection is made along the medial plane, except at the coracoid attachment, in order to avoid trauma to vessels and nerves. The tip of the coracoid, including its muscle attachment, is excised with a sharp osteotome. When the attached muscles have been retracted medially, the subscapularis muscle comes into view. The inferior border of the subscapularis musculotendinous portion is exposed. Care should be used to avoid trauma to the circumflex vessels and nerves which cross at this level above the teres major. The blunt dissection upward is started at the medial axillary foramen. The lower halves of the musculotendinous structures are dissected from the capsule, with which they are intimately associated at this point. Retracting sutures of heavy chromic catgut are placed in the medial portion of the cut muscle, and also in the tendinous portion near the lesser tuberosity. The muscle portion is retracted medially and the capsule comes into full view, with the anterior rim of the glenoid in the center of the field. Two Allis forceps grasp the capsule one inch apart, just above the rim of the glenoid; by a sharp scalpel with an offset blade, a longitudinal incision parallel to the rim is made in the capsule. It is imperative that this incision follow the rim and that it be no longer than is necessary for exploration and fixation. The joint margin is explored and the pathological changes are determined. In all cases the labrum or the capsule was found to be detached. Loose fragments of osteochondritic origin, including fragments of the labrum, when fractured, are removed from the joint. With a narrow chisel the edge of the rim is cubed to provide a surface of raw bone.

With the first cases, a harness awl, with a triangular point bent at an angle of 45 degrees, was used to make the holes from the articular cartilage of the glenoid through the bony rim. Mattress sutures of nylon were carried by a short stout needle through these holes into the lateral free flap or capsule of the humerus, approximating it with the entire area of denuded rim. The medial scapular flap was plicated over the lateral flap by two or three fine silk sutures. In order to get these sutures well placed, an assistant must exert backward and outward retraction on the upper arm to get the humeral head away from the glenoid cavity and rim. After the sutures are made in the capsule, the head of the humerus is allowed to return to the glenoid fossa and is placed in internal rotation. The subscapularis is sutured, the coracoid tip is sutured into position, and the wound is closed with as few sutures as are necessary for tissue approximation.

Downing fixed the scapular margin of the cut capsule to the rim of the glenoid by a stainless-steel staple made from a Kirschner wire. The lateral edge of the capsule was sutured to the fixed scapular edge with mattress sutures, thus everting the cut edges of the

TABLE II

Comparative Study of Capsule Fixation

End Results	Capsule Sutured (*Per cent.*)	Capsule Stapled (*Per cent.*)
No functional defect	73	62
Defect of more than 15 per cent.	18	37
Discharged to full duty	36.5	41
Discharged to limited duty	27	12
Surveyed from Service	36.5	47

capsule and eliminating any intracapsular raw edges of tissue. This resulted in building up as well as fixation of the glenoid rim. Downing devised a special instrument for inserting the staple and for retracting the subscapularis, and claimed that it was not necessary to remove the tip of the coracoid or to section the subscapularis completely for adequate exposure. By this method, which was used in the later cases of the series, the operative time was considerably shortened and the surgical trauma was lessened, although no difference could be noted in the end results from those obtained by the classical Bankart procedure (Table II).

The patients with posterior dislocations were operated upon, by use of the approach described by Rowe and Yee, which gives a very fine exposure of the posterior rim. In each of these cases, a detachment of the capsule for a distance of three centimeters was noted, and the labrum was fractured; one had a loose fragment attached to the rim by a shred of tissue. The first case was treated by suturing the capsule flap to the raw bone edge; a dental drill was used for the holes. In the other cases a stainless-steel staple was used to fix the lateral or free flap of the capsule to the raw bone rim; eversion of the edges of the capsule was accomplished with mattress sutures.

In five cases of this series the coracoid tip was not excised. The short biceps and coracobrachialis muscles were retracted medially. No difference could be noted in the end result (Table I).

The first patient selected had virtually a flail shoulder, and he could slip the humeral head over the anterior or posterior rim of the glenoid at will. He had a posterior as well as an anterior subglenoid type of dislocation. The patient had had two previous operations, first a Nicola operation and later a Henderson tenosuspension, without correction of the disability. A fusion of the shoulder joint had been advised prior to his transfer to this Hospital. The classical pathological changes in this case were those that have been described by various writers. Interest was further stimulated by the stability of the joint following the anterior capsulorrhaphy, so that the posterior procedure also was carried out at a later date. The results of these two operations for anterior and posterior repair were gratifying. Because of the complications and the perplexing problems, the following cases are reported in detail.

CASE REPORTS

Case 1. W. M. K., a white male Seaman, Second Class, aged twenty-four years, was admitted to the United States Naval Hospital on July 15, 1944, for treatment and disposition. His original injury, in 1942, was a fall of ten feet from the gangway of a ship, causing a complete subglenoid dislocation of the left shoulder; this necessitated anaesthesia and a difficult manipulation for reduction. Six weeks after injury the shoulder became dislocated while the patient was taking a shower. Reduction was made without anaesthesia and a sling was worn for two weeks. Subsequently, the shoulder dislocated frequently upon throwing the arm forward, or lifting with the arm in abduction and external rotation. After several episodes it was noted that internal rotation of the arm and reaching backward would cause a posterior slipping of the humeral head.

In October 1943, a Nicola operation was performed at a Naval hospital. Postoperative recovery was uneventful. Atrophy of the deltoid followed, with weakness of the shoulder girdle. While physiotherapy and active motion were being conducted, three months after operation, the shoulder dislocated

anteriorly. The shoulder joint was very much relaxed, and the patient could again slide the humeral head forward or backward over the glenoid rim. He was evacuated to a United States Naval Hospital in the continental United States for disposition. In January 1944, a Henderson tenosuspension was performed at that Hospital by a competent orthopaedic surgeon. After this operation, the shoulder felt weak and insecure. The patient stated that he could feel no change in the shoulder joint, and when active motion was resumed he noticed the same anterior and posterior subluxation. For several months he received physiotherapy and exercise without any improvement, and was sent to this Hospital for disposition. A shoulder fusion had previously been advised.

Physical examination revealed a tall, slender individual with comparatively poor muscle development and stooped posture. There was marked atrophy of the left shoulder girdle, particularly of the entire deltoid. There was a well-healed incision, eight centimeters in length, over the anterolateral aspect of the shoulder; and a second well-healed incision over the lateral aspect, extending distally from the acromion process for from eight to ten centimeters. Anterior elevation and abduction were slow and unsteady, with a comparative loss of 50 per cent. External and internal rotation were about the same as on the right, but subluxation of the humeral head occurred anteriorly and posteriorly, respectively. The patient could not lift more than ten or fifteen pounds with the left arm.

On August 2, 1944, an anterior Bankart operation was performed under gas-oxygen-ether anaesthesia, using the approach previously described. The operative findings disclosed a redundant thickened capsule, which was entirely detached from the glenoid rim over two thirds of the anterior rim; and a fracture of the labrum, with a loose piece three centimeters in length attached to the capsule. On the superior border of the capsule there was a vertical tear, three centimeters in length. The loose fragment was removed. The lateral or free flap of the capsule was sutured to the raw bone edge of the glenoid rim with nylon sutures. The rent in the capsule was sutured with No. 00 chromic catgut. The coracoid tip, with its muscle attachments, was sutured into position and the wound was closed without drainage. A Velpeau dressing was applied. Postoperative convalescence was uneventful, and motion was started on the twenty-first day. The anterior capsule appeared to be tight, and the head could not be dislocated anteriorly. However, the humeral head could be displaced posteriorly over the posterior glenoid rim.

On September 8, 1944, a posterior Bankart operation was performed, by use of the posterior approach described by Rowe and Yee. The operative findings disclosed a detachment of the capsule from the posterior glenoid rim, and a fracture defect three and one-half centimeters in length. The fragment was removed, the rim was denuded over the defect, and the free flap of capsule was sutured to the rim with nylon and plication of the scapular flap of capsule. The wound was closed in layers. A Velpeau dressing was applied to the arm and a sponge rubber doughnut ring was placed over the posterior aspect of the humeral head. The postoperative period was relatively free from pain; the highest temperature was 100.2 degrees on the second day after operation. There was no drainage from the wounds, which healed by first intention.

Active motion was started on the twenty-first day, using the Codman procedure of circumduction and later the shoulder-girdle exercises.

The patient was hospitalized under treatment for a further period of three months. There remained a limitation in external and internal rotation and abduction; the latter was due largely to the atrophy of the deltoid which had been present upon admission. Seventy-five per cent. of the normal range of motion was present, although the motor power of the entire shoulder girdle was weakened. No recurrence of dislocation or subluxation had taken place when the patient was discharged from the Naval Service on January 2, 1945.

Case 6. D. G. B., a white male Machinist's Mate, Second Class, aged twenty-seven years, was admitted to the United States Naval Hospital on February 4, 1944, for treatment and disposition. His original injury was sustained on September 10, 1942, when a dock crane tipped and he was thrown backward, falling on his extended arm. A subglenoid dislocation occurred with a sliver fracture of the greater tuberosity. Reduction was accomplished under anaesthesia, and a sling was worn for three weeks. Subsequently, the patient stated he had had frequent dislocations, totaling about fifty. On February 8, 1944, a Nicola operation was performed. No dislocation occurred, but the patient had a limitation of abduction and anterior elevation, with pain. He was discharged to limited duty. On July 5, 1944, he slipped, and in catching himself, dislocated the shoulder. No anaesthesia was required for reduction. On July 11, 1944, examination disclosed a loss of 35 degrees in anterior elevation, 25 degrees in abduction, and 10 degrees in internal and external rotation, with pain. Several dislocations followed.

On September 27, 1944, a Bankart capsulorrhaphy was performed from the usual approach, including section of the coracoid tip and the tendon of the subscapularis muscle. There were dense adhesions with extensive oozing, and the muscle planes were difficult to follow. The operative findings revealed a T-shaped tear in the anterosuperior portion of the capsule, and a tear of the glenohumeral ligament. There was a fracture of the labrum on the inferior border, although the capsule was not detached except for a small area at the site of fracture. The biceps tendon was intact but appeared to be stretched. The tear in the capsule was sutured with fine chromic catgut. The lateral flap of the capsule was sutured to

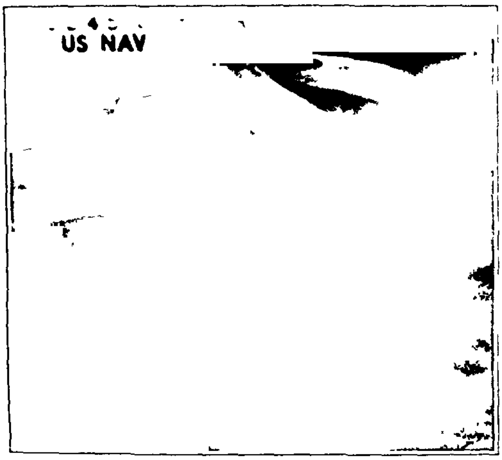

Fig. 1-A

Case 29. Roentgenogram taken with arm in abduction. The head is in normal opposition to the glenoid cavity.

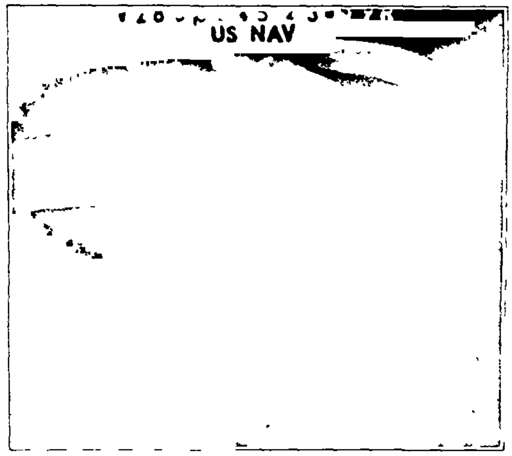

Fig. 1-B

Roentgenogram taken with arm in abduction and internal rotation. This position produces posterior subluxation of the humeral head over the rim of the glenoid. Note relaxation of the capsule to permit the wide joint space, and the increased space between acromion and greater tuberosity.

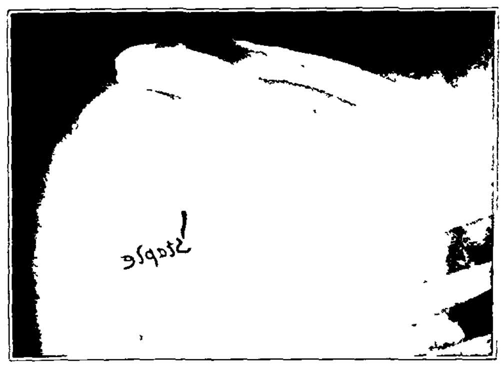

Fig. 1-C

Roentgenogram three weeks after operation, showing staple in posterior rim of glenoid, and humeral head in normal relation to glenoid.

the raw bone rim with nylon, mattress sutures, and plication of the medial flap. For two weeks, dressings were performed with the arm on a 45-degree abduction splint, and then a sling was worn for three weeks. There was severe pain for the first five days. On the sixth day the patient's temperature rose to 102 degrees and a large hematoma was evacuated from the lower end of the incision. Drainage continued for a few days and healing was complete at the end of three weeks, at which time motion was started. Physiotherapy and active motion were continued.

On October 30, 1944, the patient was transferred to a convalescent hospital. On November 20, 1944, while he was receiving physiotherapy and manipulation, the lower end of the wound opened and fresh bleeding occurred. The wound again healed, after a slight serous drainage for three weeks. Motion at that time showed a loss of 10 degrees of external rotation, 30 degrees of abduction, 70 degrees of anterior elevation, and a 10 per cent. limitation of circumduction. Physiotherapy was continued; improvement followed. There was considerable pain in the extremes of all motions.

The patient was discharged from the Service in March 1945, with a range of motion which was about 90 per cent. of normal, but which was painful in abduction and external rotation. There was some keloid of the operative scar, for which roentgenotherapy was given prior to discharge from the Hospital.

Case 29. C. R. P., a white male Corporal in the United States Marine Corps, aged twenty years, was admitted to the United States Naval Hospital on July 18, 1945, for treatment of recurrent dislocation of the right shoulder. His first injury was sustained in 1940, while he was playing football. The dislocation was reduced without anaesthesia by a doctor at the athletic field. There was no recurrence until a second injury occurred in 1943, when the patient fell from the tail gate of a moving truck. His dislocation was reduced by a hospital corpsman without anaesthesia. The description given was a posterior subluxation; both injuries occurred while the arm was internally rotated and abducted. Since the injury in 1943, the patient had noticed a relaxation of the joint, and he could subluxate the humeral head over the posterior glenoid rim at will.

Examination revealed a well-developed, slender individual with no unusual joint relaxation except of the right shoulder. There was a full range of scapulohumeral motion of the right shoulder, and the patient could demonstrate a posterior subluxation of the head by internal rotation and abduction of the arm. The head could be palpated while sliding over the rim; this was verified by fluoroscope and by roentgenogram (Figs. 1-A and 1-B).

On August 28, 1945, a Bankart capsulorrhaphy was performed, with the posterior approach. Operative findings disclosed a detached capsule and a fracture of the labrum and rim, on the posterior sector. The scapular edge of the cut capsule was stapled to the posterior glenoid rim, and the humeral edge of the capsule was plicated over this and sutured with chromic catgut. Recovery was uneventful. Motion was started on the twenty-first day, and consisted of physiotherapy and active exercises. Seventy-five per cent. of motion was present (Fig. 1-C).

Examination on October 4, 1945, revealed a well-healed scar over the posterior aspect of the shoulder joint, with slight deltoid atrophy. Extension and flexion were the same as on the left. Abduction was equal to that on the left. Anterior elevation was 15 degrees less than on the left. Internal rotation had a few degrees of limitation. External rotation was almost equal to that on the left. With the arm in internal rotation and abduction, the head could be subluxated or slipped over the posterior rim. There was slight weakness in the muscle power of the shoulder girdle. The range of motion was 95 per cent. of normal. The patient will be discharged to duty.

A Velpeau dressing was used in all cases, and the upper arm was secured to the body for a period of fourteen days to prevent external rotation and abduction. The patients were permitted bathroom privileges after five days, and were confined to the ward for ten days. Motion was started about the twenty-first day, and only a sling was used. Circumduction, in the manner described by Codman for postoperative shoulder cases, was started at this time. Carefully supervised physiotherapy was used on all patients until a maximum range of motion was obtained.

All patients had sufficiently recovered to be discharged from the hospital at the end of from ten to fourteen days, but military routine necessitated hospitalization until they were fit for duty. Twenty-seven of these patients could have returned to light duty at the end of four weeks, or could have returned to office work after fourteen days. No limited duty was available at the time of convalescence for most of these patients; consequently, the period of disability is of no value statistically.

Trauma was found to be a very definite factor in this series; trauma from accident or injury occurred in twenty-nine cases, or 97 per cent. Repeated accidents or traumata were found in 50 per cent. of the cases. The one epileptic could not recall any accident; the first dislocation occurred during an attack of petit mal.

The dislocations were predominantly of the anterior and subglenoid type; there were six cases of each, and fourteen cases which combined the two types. Four were posterior, and one of these combined all three types.

The pathological findings were conclusive: all of the cases had a detachment of the capsule from the rim at the site of the fracture or defect. There were twenty-one cases, or 73 per cent., with a fracture of the labrum. Fifteen cases presented osteochondritic or degenerative changes of the humeral head, with a typical osteochondritis dissecans, one centimeter in diameter, lying in the joint cavity. Eight cases had a definite notch defect in the rim, demonstrable by roentgenogram. Only one case with a defect of posterior notching of the humeral head was noted. One case had a hatchet-shaped deformity of the head, attributed to a fracture sustained several years prior to operation.

In four cases dislocation had recurred after the Nicola operation; one of the patients had had a tenosuspension operation after the Nicola operation, with recurrence. Three cases had definite tears or defects in the superior border of the capsule, involving the musculotendinous cuff, as described by McLaughlin.

CONCLUSIONS

Inasmuch as approximately sixty different operations have been devised for the treatment of recurrent dislocation of the shoulder, each productive of a degree of success, it would appear that to date there has been no wholly dependable operation for complete cure of this malady.

The present series would indicate that we must attack the site of pathological changes in order to procure a more satisfactory result, and since the changes seem to be constant

in the capsule and the joint cavity, a method of capsulorrhaphy would be the most logical therapeutic measure.

Compensatory muscle, tendon, or fascial support has not been found adequate in these cases, nor has their plastic repair or substitution been sufficient.

This method of capsulorrhaphy causes no intra-articular damage, the joint cavity remains intact with no more trauma than is produced by the arthrotomy, and the repair is made at the site of trauma with an attempt to overcome the insufficiency of the glenoid cavity.

The incidence of recurrence must be evaluated after a period of years, rather than of months, in order to determine the final proof of any one procedure. Eighteen months without recurrence has been the longest period of observation made by the author.

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ROTATION OSTEOTOMY

A Method Employed in Cases of Congenital Club-Foot

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In the newborn, there is normally an inward rotation of the foot, which may be measured by the angle formed by the transverse axes of the ankle joint and the knee joint. The inward rotation in the newborn is normally considered to be 10 degrees. A continuous outward rotation of the foot usually takes place during growth, so that the two axes are parallel at the age of ten. In adults, the axis of the ankle joint is rotated 23 degrees outward in relation to that of the knee joint.[5]

It is a well-known fact that inward rotation is increased in most patients with congenital club-foot. This increased inward rotation must be considered a "normal" component in the type of foot deformity which is called talipes equinovarus congenitalis. The inward rotation in congenital club-foot is reported to be as much as 40 degrees or more.

Compared with the other faulty positions which make up the deformity called club-foot (talipes varus, talipes adductus, and talipes equinus), the increased inward rotation and its treatment have not attracted much interest. This may be ascribed partly to the fact that an inward rotation is not so conspicuous as other faulty positions, and partly to the circumstance that this deformity may have been considered less important from the point of view of therapy and prognosis than the equinus, varus, and adductus deformities. Even if the last-mentioned point of view may seem warranted to a certain extent, an increased inward rotation cannot be considered entirely unimportant. If it remains after the other deformities have been corrected, the patient will propel his foot over its lateral border when walking. In the last phase of a step, the foot is thus forced into varus position. This entails a bad gait and a risk of recurrence of a varus deformity which had been well corrected; and in these cases, this is a considerable risk. In patients with remaining inward rotation of the foot, especially where this rotation is great, the peroneal muscles are lengthened and the anterior tibial muscle is shortened; a state of contraction in the anterior tibial muscle, resulting in an increased varus tendency, may thus easily be produced.

The treatment of increased inward rotation may be either conservative or operative.

Conservative treatment is carried out either as a part of the plaster correction of the equinovarus position, or, later, by means of mechanical devices. A number of such apparatus, more or less complicated, have been constructed.[3] The method employing the spiral bar constructed by Heusner is in most general use today.[12]

Several methods have been suggested for operative correction of inward rotation. All of these methods recommend a transverse osteotomy of the tibia at its *lower third*,[1,3,6] in most cases followed by transverse osteotomy or osteoclasis of the fibula at the same level. Some authors[7,8,11] have performed osteotomy of the tibia only. Others have proposed either a transverse osteotomy *at the middle of the tibia without osteotomy of the fibula*,[2] or osteotomy of the lower part of the femur.[8] Stirling describes a method with oblique osteotomy at the middle of the tibia, while the fibula is left intact. After the osteotomy, the inward rotation is corrected, and plaster is applied from the toes to the groin. The plaster is kept in position for from four to six weeks.

There are certain disadvantages to all of these operations. If the operation is limited to osteotomy of the tibia, an inward rotation cannot be entirely corrected. The medial malleolus rotates with the distal end of the tibia, while the lateral malleolus remains unchanged. For this reason, the joint surfaces of the malleoli are no longer congruent with the joint surfaces of the lateral and medial part of the astragalus. This may limit move-

ment of the ankle joint, and increases the risk of recurrence. Similar results are obtained in patients in whom osteoclasis of the fibula has been performed, in addition to osteotomy of the tibia.

Where osteotomy or even resection of the fibula has been done at the same level as osteotomy of the tibia, it is possible to produce a real derotation. There is, however, a risk that a faulty position at the site of the osteotomy may be obtained, coincident with correction of the inward rotation.

In order to eliminate the difficulties mentioned, the following method for performing rotation osteotomies has been employed by the author since 1940. So far as is known, this method has not been described. The operations have been carried out at the Vanföreanstalt in Gothenburg and at the Orthopaedic Clinic in Lund.

A transverse osteotomy is made subperiosteally within the lower third of the tibia. Then an oblique osteotomy of the fibula is made within its upper third. In order to avoid injuring the peroneal nerve, the osteotomy should not be too close to the neck of the fibula. The incision is best made over the anterior intermuscular septum which divides the extensor digitorum longus from the peroneal muscles. The incision should then continue behind the septum, as this is the best way of reaching the fibula. At this level the superficial peroneal nerve runs along the short peroneal muscle, but it is not difficult to avoid. The osteotomy of the fibula should also be made subperiosteally, and care should be taken to ascertain that the periosteum is well elevated from the back of the fibula to prevent a lesion of the posterior fibular artery. As a matter of fact, the posterior *tibial* artery may sometimes be missing or run along the back of the tibia as an unimportant vessel, and in such cases the posterior *fibular* artery has to carry the whole burden of supplying the vascular area of the tibial artery. After the osteotomy, a full-length leg cast is applied and maintained for six weeks.

This operative procedure affords the following advantages: (1) The risk of faulty positions in the tibial osteotomy is practically eliminated, as the fibula, untouched in its lower part, serves as a stabilizer. (2) A real derotation of the foot can be performed with maintained congruence between the joint surfaces of the malleoli and the sides of the astragalus. (3) It is easier for the surgeon to control the derotation by this method than by other methods. The correction is easily made, and no violence is necessary even in patients with very high degrees of inward rotation. The degree of correction is easily adjusted to the demands in the individual case.

At the Vanföreanstalt in Gothenburg and at the Orthopaedic Clinic in Lund, the writer has performed seventeen rotation osteotomies on thirteen patients, according to this method, since 1940. Of these patients, eight have been observed for from two to two and a half years, and five for from three to four years following operation. No recurrence of inward rotation has taken place, and the position of the feet has been very good in all cases.

Rotation osteotomy is indicated principally in cases in which the equinus, varus, and adductus deformities have already been corrected; but where, in spite of this, an increased inward rotation remains, so that the patient propels his foot over its lateral border. This also implies that rotation osteotomy should be resorted to only when the correction possible by conservative treatment has been completed, and after other operative measures, such as achillotenotomy, have been undertaken.

Note: The author wishes to thank H. Camitz, M.D., Chief of the Vanföreanstalt, Gothenburg, and Gunnar Wiberg, M.D., Chief of the Orthopaedic Clinic, Lund, for placing this material at his disposal.

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DEFORMITIES FOLLOWING SURGICAL EPIPHYSEAL ARREST

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Reports on lengthening and other methods of equalizing the length of the lower extremities when discrepancies occur after infections, trauma, congenital deformities, and paralyses in children stimulated Phalen and Chatterton to review their cases at the Gillette State Hospital in which operations for lengthening and shortening the lower extremities had been performed. The authors have undertaken a review of the cases of epiphyseal arrest for unequal limb length, because of a number of deformities which were observed in the Out-Patient Clinic of the same Hospital in patients who had undergone this surgical arrest of growth in the lower extremities.

EQUALIZATION OF LENGTH OF THE LOWER EXTREMITIES

Discrepancy in the length of the lower extremities may become a disability severe enough to warrant surgical intervention, depending upon the amount of difference in the length of the two limbs. In differences of one inch (2.5 centimeters) or less, compensatory motion of the pelvis and spinal column usually takes care of the discrepancy. Shortening of a limb of more than one inch usually leads to excessive tilting and curvature of the spinal column, with resultant muscular fatigue and symptoms of strain. Furthermore, the psychic effect of a short limb and conspicuous appliances, such as lifts or pattens on the shoe, usually prompts either the patient or his parents to seek relief for the condition.

Inequality in limb length may be caused either by retarded growth or by increased growth in the extremity. Loss of bone substance following accidents may also terminate in limbs of unequal length. The growth of bone may be altered by various diseases of bone, such as rickets and acute and chronic infections in or about the metaphysis. Trauma, the action of various endocrine glands, and various affections of the nervous system may also alter the structural growth of bones. Congenital deformities of bones and joints, as well as benign bone tumors and acquired or congenital vascular conditions, may be factors in producing inequality of growing bones.

One of the most common types of overgrowth in bone is that resulting from chronic osteomyelitis in the juxta-epiphyseal region of the long bones, even without actual invasion of the epiphyseal cartilage itself. It has been noted by many observers that retardation, rather than stimulation, of growth of epiphyseal cartilage usually results from minimum trauma or epiphyseal invasion by avirulent micro-organisms.

Attempts have been made to equalize the length of extremities, while growth is still in progress, by stimulation as well as by retardation. Although Wilson and Thompson have reviewed the literature and have given an excellent critical analysis of the methods available to equalize limb lengths, a few notes as to the historical background may be necessary.

As early as 1867, Ollier observed that irritation of the shaft of a growing bone resulted in an increase in the rate of growth.

After sympathectomy, which had been done primarily to enhance the blood supply to the limbs, Harris noted an increase in the growth of extremities which were paralyzed following acute poliomyelitis and showed variations in the vasomotor supply, manifested by coldness, changes in color, and paraesthesia. The epiphyseal growth was stimulated

TABLE I

Etiology of Discrepancies in the Length of the Lower Extremities

Etiological Factor	Number of Cases
Anterior poliomyelitis	24
Congenital shortening	3
Septic arthritis	
Hip	1
Ankle	1
"Infectious process involving epiphysis of knee"	1
Spina bifida	1
Tuberculosis	
Hip	1
Knee	1
Epiphysiolysis of hip	1
Chronic osteomyelitis with overgrowth	2
Total	36

with the increase in circulation to the extremity. Wilson and Thompson, in a later report, found that the increase in rate of growth was too slight and too inconstant to justify recommending sympathectomy as a method of equalizing limb length.

Brooks and Hillstrom have shown that growth of the cartilage cells of the epiphyses can be delayed or completely inhibited by exposure to roentgen rays. Clinically, however, serious damage to the articular structures seems almost inevitable.

It remained for Phemister to report a method of attempting the limitation of growth of the longitudinal bone by surgically disrupting the growing epiphyses of the longer limb when unilateral shortening or lengthening had occurred.

The decision as to when the arrest should be performed is more difficult than the actual technique of operative procedure. Also, the epiphyses to be fused must be considered. It is possible to *produce overshortening in the extremity upon which operation is* performed, since the epiphyses of the short limb may still produce sufficient growth, although it has been diminished, to overtake the extremity which has been arrested to too great an extent. Straub, Thompson, and Wilson have recorded such a case.

Digby determined the average proportional growth at various epiphyseal lines, and his calculations are used by many surgeons in determining their operative sites. Certain complicated methods have been propounded for determining the optimum age for operation and the sites for fusion.

White and Stubbins stated that, regardless of the age and size of the growing patient, arrest of growth of the distal femoral epiphysis retards growth at the rate of three-eighths of an inch (1 centimeter) a year, while arrest at the proximal end of the tibia (and of the fibula) retards growth one-quarter inch (0.6 centimeter) a year. They also mentioned an important item,—namely, that epiphyseal growth ceases in girls at sixteen years of age and in boys one year later. They recommended that epiphyseal arrest be performed in children at the age of ten or twelve years, if there is a shortening of more than two inches (5 centimeters), so that by the time growth ceases, approximate equalization can be expected.

Wilson and Thompson stated that, if only a moderate retardation of growth seems indicated, the decision as to whether epiphyseal arrest should be performed above or below the knee depends on whether the shortening in the opposite extremity is greater in the thigh or in the leg.

Objections to epiphyseal arrest, as to some other methods of equalizing limb length, arise because of the necessity of surgically attacking the uninvolved extremity and, in so doing, subjecting it to the possible risks attendant upon any surgical procedure.

TABLE II

DATA ON THIRTY-SIX CASES OF SURGICAL EPIPHYSEAL ARREST

Bones in Which Epiphyses Were Arrested	Age at Time of Arrest (*Years*)	Discrepancy at Time of Arrest (*Inches*)	Length of Follow-up (*Years*)	Discrepancy at Time of Follow-up (*Inches*)
		Males		
Femur, tibia, and fibula (Case 1)	11	1¼	4	¾ (Deformity)
Femur, tibia, and fibula (Case 4)	14	1¾	3	¾ (Deformity)
Femur, tibia, and fibula	14	3	2	1½
Femur	12	1¾	2	1¼
Tibia and fibula	13	2	1	¾
Femur, tibia, and fibula	13	2½	1	1½
Femur, tibia, and fibula	13	1½	1	1½
Tibia and fibula	12	2	1	1¾
Femur, tibia, and fibula	13	2½	1	½
Femur, tibia, and fibula	15	2½	1	2½
Femur, tibia, and fibula	12	4	1	3¼
Tibia and fibula	13	1	1	½
Tibia and fibula	13	1½	1	¾
Femur, tibia, and fibula (Case 2)	11	1¾	1	½ (Deformity)
Tibia and fibula (Case 3)	11	1¼	1	1 (Deformity)
		Females		
Femur, tibia, and fibula	13	1	8	1
Femur, tibia, and fibula	10	2¾	7	2
Femur, tibia, and fibula	12	2	7	½
Femur, tibia, and fibula	13	2	7	Equal
Femur, tibia, and fibula	13	2	6	1½
Tibia and fibula	12	2	4	2
Femur, tibia, and fibula	10	2⅜	4	3¼
Femur, tibia, and fibula	12	2	3	1¼
Femur	11	3½	3	2¼
Femur	10	2	3	⅜
Femur	10	1¾	3	½
Femur	10	1¼	3	¾
Femur, tibia, and fibula	12	1½	1	1⅛
Femur	12	1½	1	1¼
Femur, tibia, and fibula	14	1⅞	1	1
Femur, tibia, and fibula	13	1	1	1
Tibia and fibula	10	1¼	1	1¼
Tibia and fibula	10	1	1	¾
Femur, tibia, and fibula	11	2¼	1	2
Tibia and fibula	12	1¼	1	1
Femur, tibia, and fibula	11	2¼	1	1⅛

POSTOPERATIVE DEFORMITIES

Deformities attributable to surgical epiphyseal arrest are apparently not common. Compere reported more than 100 cases of epiphyseodesis of the lower extremity, without complications. In a review of sixty-six cases of surgical arrest in the lower extremity, Steindler found no deformities attributable to the epiphyseal fusion. Campbell mentioned the possibility of asymmetrical fusion with subsequent deformity (genu varum, genu valgum, or genu recurvatum). He had observed two cases of slight genu valgum following arrest, in which the deformity was not enough to warrant surgical correction. In another case, definite genu recurvatum developed three years after arrest by the Phemister method. Wilson and Thompson stated that, although late deformities had not been reported, they had observed three cases in which operation was performed according to the Phemister technique, and in which there developed disalignment at the knee sufficient to warrant operative correction. Straub, Thompson, and Wilson, in a recent study of their cases of epiphyseal arrest, found that deformities resulting from unequal arrest constitute a serious hazard. Deformities usually developed within a year after operation.

Of eighty-nine patients upon whom epiphyseodesis was done, fifteen showed deformities. Eight deformities were severe enough to warrant corrective operation. In seven of these fifteen cases the type of deformity was genu valgum, in six it was genu varum, in one it was varus of the lower femoral segment and valgus of the upper tibial segment, and in one case the deformity was not recorded.

Campbell explained the development of genu valgum on the basis of technical error, since the approach to the lateral surface of the tibial epiphysis is more difficult than the approach to the medial surface, and the tendency is for the surgeon to arrest the anterolateral part of the epiphysis rather than the lateral portion. In the case of genu recurvatum following arrest, which he mentioned, only the anterior part of the epiphysis of the tibia was arrested and the posterior part continued to grow, resulting in an anterior tilting of the articular surface of the tibia. Straub, Thompson, and Wilson believed that the deformities they noted resulted from faulty technique, especially in the preparation and placing of the bone grafts. In their opinion, contributory factors in the production of deformities may be the lack of plaster-of-Paris immobilization and too early weight-bearing.

REVIEW OF CASES

This report includes all surgical epiphyseal arrests performed from June 1, 1933, to December 31, 1943, inclusive, which afforded a postoperative check-up of at least one year prior to December 31, 1944. During this period of ten years and seven months, a total of thirty-six patients underwent operation for epiphyseal arrest for inequalities of limb length. The etiological factors responsible for discrepancies in the length of the lower extremities in this series (Table I) seem to coincide with those observed by other writers. Tabulations were made of the sex, epiphyses arrested, age at time of operation, amount of discrepancy in length of limbs at the time of operation and at the time of follow-up, and length of follow-up period (Table II). It is obvious that in some instances equalization did not occur, yet the procedure arrested progressive discrepancy. Deformities following arrest

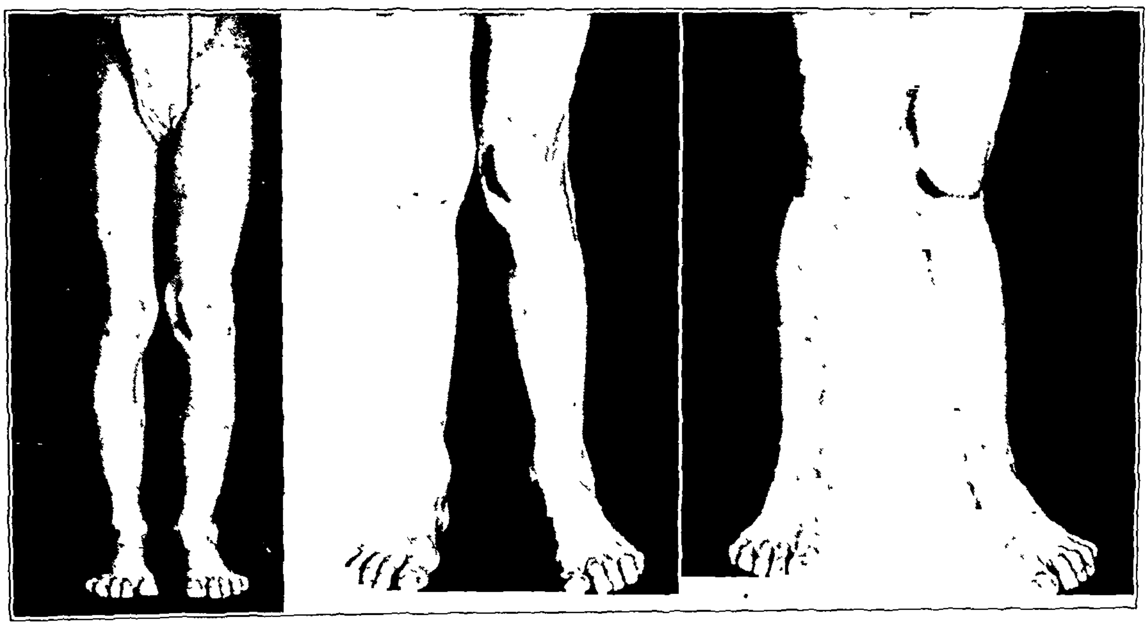


Fig. 1-A Fig. 1-B Fig. 1-C

Lower extremities in Case 1.

Fig. 1-A: Before arrest. Note apparently equal length; there was compensatory tilting of the pelvis, which is not shown.

Fig. 1-B: One year and six months after arrest. Note increasing valgus deformity of the left knee.

Fig. 1-C: Four years after arrest.

November 1940
FIG. 1-D

June 1944
FIG. 1-E

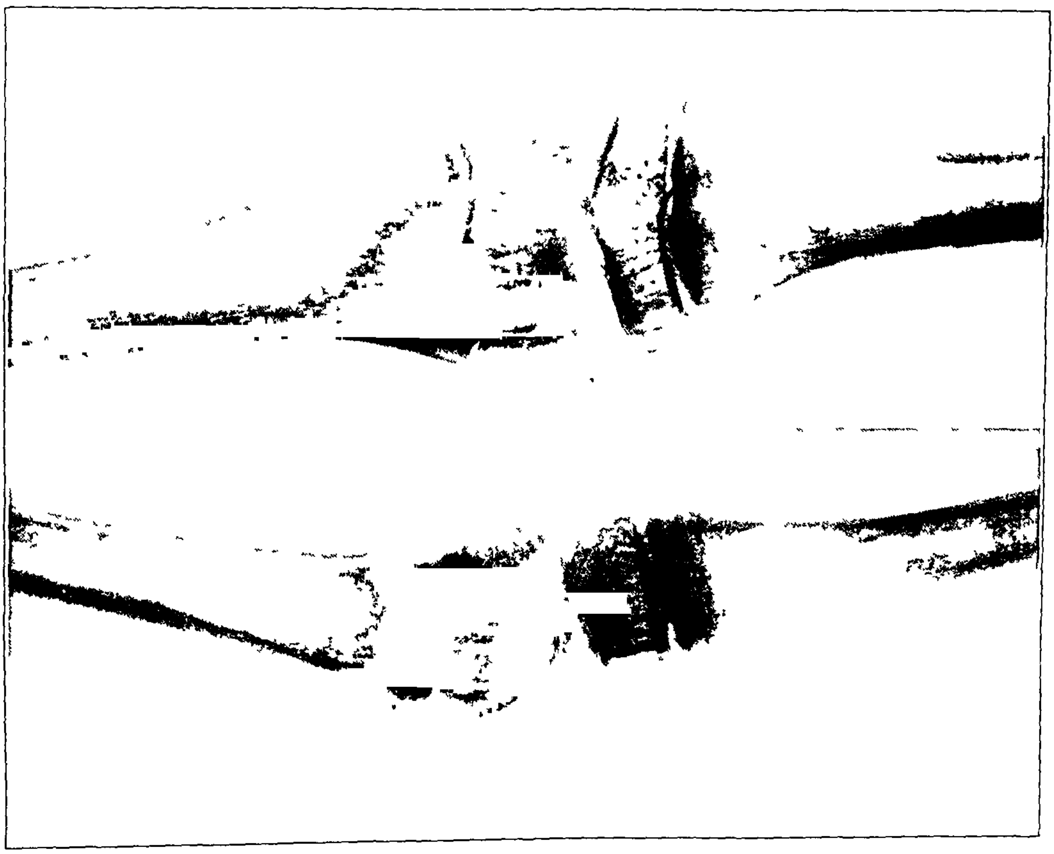
Anteroposterior roentgenograms of the left knee. Compare the deformities of the bone with those shown in Figs. 1-A and 1-C. In Fig. 1-E only the lateral portion of the tibial epiphysis has fused; the medial part is apparently growing.

and directly attributable to the procedure occurred only in males in this series; this fact, of course, is of no significance in determining the outcome of the operation.

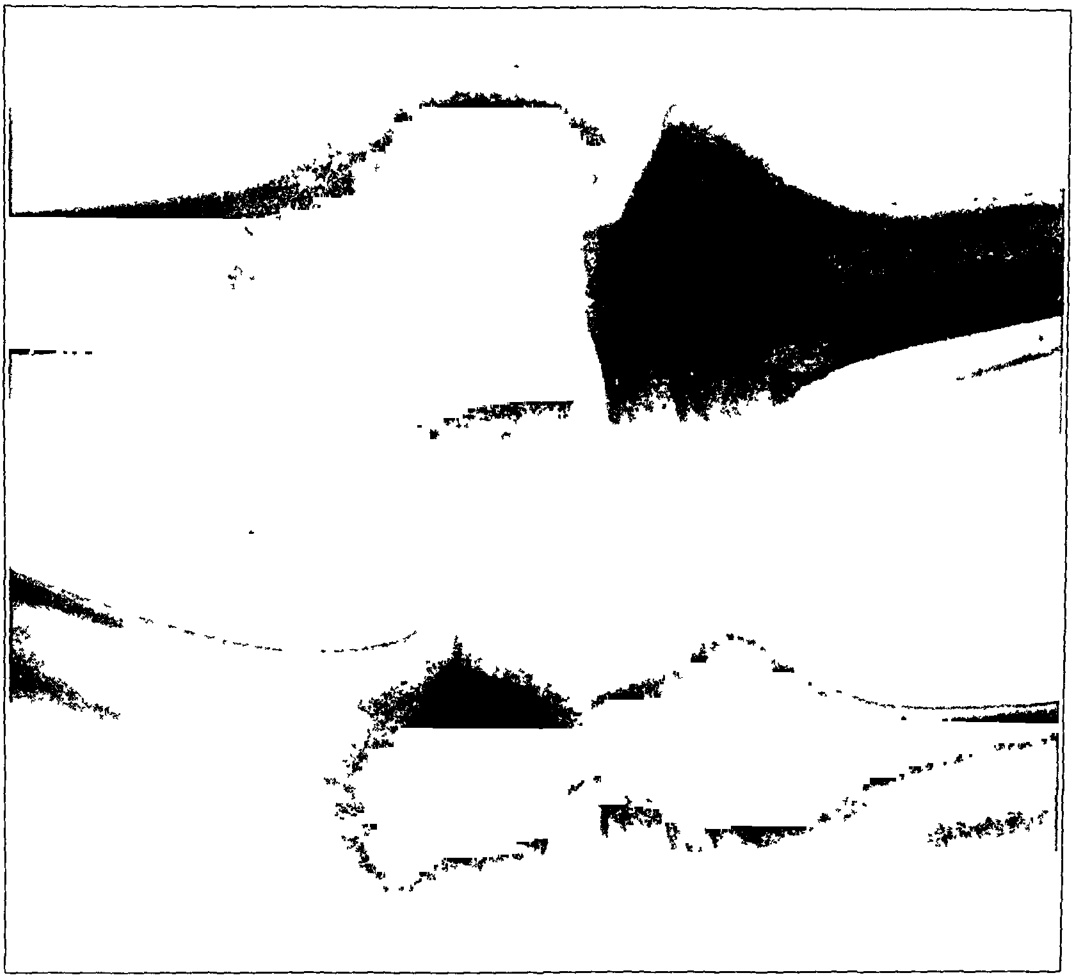
The technique of Phemister was followed in all cases, with slight modifications, depending on the individual surgeon performing the operation.

Of the thirty-six patients, four showed noticeable deformity in from two months to two and one-half years after arrest had been attempted. In Cases 1, 2, and 3, corrective surgical procedures were performed after the deformity occurred. In Cases 2 and 3, rearrest of the epiphyses was performed at the time of the corrective operation. In Case 1 the deformity recurred after correction, and probably rearrest should also have been done; the patient will need further surgical treatment. In Case 4 the authors contemplate corrective osteotomy, if the deformity increases.

CASE 1. The clinical diagnosis was atrophy and shortening of the right lower extremity, following poliomyelitis. The lower extremities of the patient before, and at two periods after, arrest are shown in Figures 1-A, 1-B, and 1-C; roentgenograms of the left knee are shown in Figures 1-D and 1-E. At the first examination in 1931, the right lower extremity was one-quarter inch (0.6 centimeter) shorter than the left. In April 1940, it was one and one-quarter inches (3.2 centimeters) shorter than the left (Fig. 1-A). In September of the same year, when the patient was eleven years of age, arrest of the left lower femoral epiphysis was performed. One month later, the left upper tibial epiphysis was arrested. Three months afterward there was noticeable valgus deformity of the left knee, and the right lower extremity was one and one-quarter inches shorter than the left. In June 1941, the upper epiphysis of the left fibula



June 1943
Fig. 2-A



November 1944
Fig. 2-B

Lateral and anteroposterior roentgenograms of the right knee. Note arrest at medial aspect of tibial epiphysis, and apparently growing lateral portion.

was arrested. In February 1942, because of the deformity (Fig. 1-B), wedge osteotomy of the lower end of the left femur was done to correct the valgus of the knee. When examined five months later, the limb was straight. The valgus had recurred when the patient was seen again in March 1944 (Fig. 1-C). This was progressive and in June 1944 (Fig. 1-E), a valgus of the left knee amounting to 25 degrees, with a shortening of the right lower extremity amounting to three-quarters of an inch (1.9 centimeters), was recorded. A note was made that further corrective surgical treatment was contemplated.

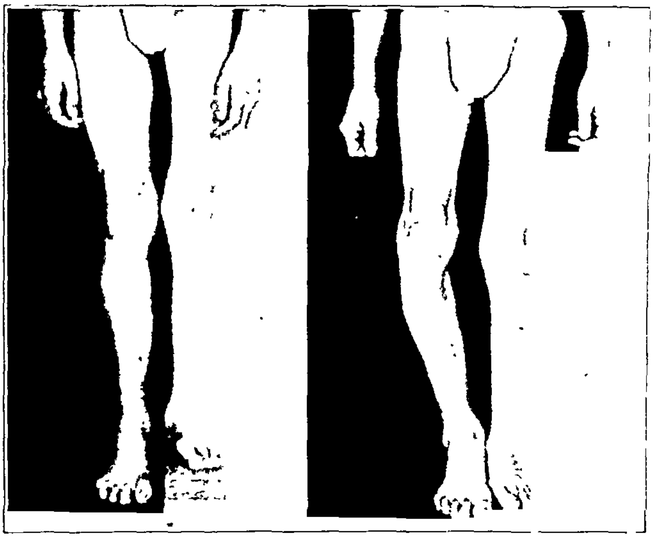


FIG. 2-C FIG. 2-D

Lower extremities in Case 2.

Fig. 2-C: Before arrest.

Fig. 2-D: One year and five months after arrest. Note varus deformity of right knee.

CASE 2. The clinical diagnosis was paralysis and atrophy of the left lower extremity, following poliomyelitis at two years of age. The lower extremities of the patient before and after arrest are shown in Figures 2-C and 2-D; roentgenograms of the right knee are shown in Figures 2-A and 2-B. The patient had been observed from time to time since 1934, one year after the acute attack of poliomyelitis. At the initial examination in November 1934, there was shortening of the left lower extremity, amounting to one and one-eighth inches (2.9 centimeters). During the following seven years there was a slow, progressive shortening, and in 1943 the left lower extremity was one and three-quarters inches (4.4 centimeters) shorter than the right (Fig. 2-C). In September 1943, when the patient was eleven years of age, arrest of the right lower femoral and of the upper tibial and fibular epiphyses was done. Two months afterward there was beginning varus deformity of the right knee, with shortening of the left lower extremity of one-half inch (1.3 centimeters). This, of course, was an inaccurate measurement, due to the deformity. When the patient was seen one year and five months after arrest, the deformity had increased (Fig. 2-D) and corrective osteotomy of the right tibia was performed.

CASE 3. The clinical diagnosis was paralysis and atrophy of the left lower extremity, following poliomyelitis at two years of age. When the patient was seen in 1933, one year after the acute attack of poliomyelitis, the limbs were of equal length. Four years later the left lower extremity was three-quarters of an inch (1.9 centimeters) shorter than the right. In June 1941, when the patient was eleven years of age (Fig. 3-A), there was shortening of one and one-quarter inches (3.2 centimeters). The right upper tibial and fibular epiphyses were arrested at that time. One year later the discrepancy had decreased by one-quarter inch (0.6 centimeter). In May 1943, valgus deformity was present (Fig. 3-B). One month later rearrest was done, and in January 1944, wedge osteotomy of the upper end of the right tibia was done for correction of the deformity.

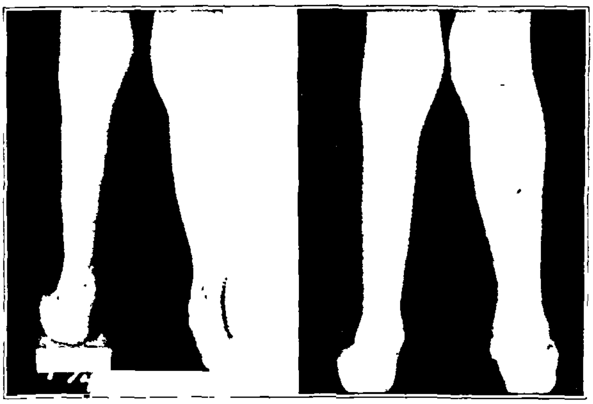


FIG. 3-A FIG. 3-B

Lower extremities in Case 3.

Fig. 3-A: Before arrest.

Fig. 3-B: One year and eleven months after arrest. Note the valgus deformity on the right and the apparent equalization of limb lengths.

CASE 4. The clinical diagnosis was paralysis and atrophy of the right lower extremity, following poliomyelitis at three years of age. This patient was first seen in January 1941, at which time there was shortening of the right lower extremity, amounting to about one and one-quarter inches. One year later the shortening was

one and one-eighth inches (2.9 centimeters). In July 1941, measurements showed shortening of one and three-quarters inches (4.4 centimeters), and, as the patient was fourteen years of age arrest of the left lower extremity was done in the lower femoral and the upper tibial and fibular epiphyses. The patient showed an excellent progressive equalization until his last visit in January 1944, when, for the first time, the knee showed a valgus deviation of 15 degrees and the right lower extremity was three-quarters of an inch (1.9 centimeters) shorter than the left. If the deformity increases, which is doubtful since the patient has reached his seventeenth year and normally should have little more epiphyseal growth, a corrective operation will be done.

COMMENT

The authors believe that complications are few following epiphyseal arrest by the Phemister method, when it is performed under adequate conditions and by competent surgeons. Postoperative wound infections are rare, since the incisions are relatively small and the operating time is short. If surgical asepsis is practised, there should be no subsequent suppuration.

Wilson and Thompson concluded that epiphyseal arrest has the advantage over the other operative methods (sympathectomy, limb lengthening, and limb shortening) of being a relatively minor surgical procedure. Careful calculation is necessary to determine the age at which the operation should be performed, and which epiphysis should be subjected to fusion. When a gross discrepancy of length is to be overcome, the operation must be performed early. Complete fusion must be obtained in order to avoid any danger of later deformity due to asymmetrical growth. In their opinion, in which the authors concur, this method offers the simplest and safest means of equalizing limb length. Unfortunately, its application is limited to the period of bone growth.

SUMMARY

In four of thirty-six cases of surgical epiphyseal fusion (carried out according to the technique of Phemister), deformities followed and were directly attributable to the operation. These deformities resulted from incomplete and asymmetrical arrest of epiphyseal growth and often necessitated further surgical intervention.

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LAG-SCREW FIXATION IN FRACTURES OF THE TIBIAL TUBEROSITY

BY MAJOR MILTON C. COBEY

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There are several reasons why fractures of the tibial plateau frequently result in disability. Among these is faulty reduction and inadequate fixation during the period of healing. An excellent reduction may be lost while the limb is fixed in a cast. Genu varum or genu valgum, resulting from incomplete reduction and inadequate fixation of the fracture, creates a faulty weight-bearing line through the knee joint. Open reduction makes possible accurate replacement of fragments.

Five years ago the author began to use a vitallium lag screw of the Lippmann type in order to maintain reduction of these fractures. The screw prevents outward displacement of fragments. At the same time it may be so directed as to counteract any tendency to depression of the plateau, an advantage which the through-and-through bolt does not possess.

The ability of the corkscrew or lag screw to hold firmly in cancellous bone has been demonstrated by both Lippmann and Henderson in fractures of the femoral neck. Trabecular bone requires the large surface grip of the corkscrew. An ordinary vitallium wood screw is not sufficient. The lock washers of the through-and-through bolt are, in the author's opinion, too small to hold the fragments in three planes. In addition, the line of the bolt must be nearly in the coronal plane to ensure protrusion of the end for the application of the lock washer and nut. The author feels that this coronal position of the through-and-through bolt tends to lose the desired elevating force on the fragments, and affords only an impacting force.

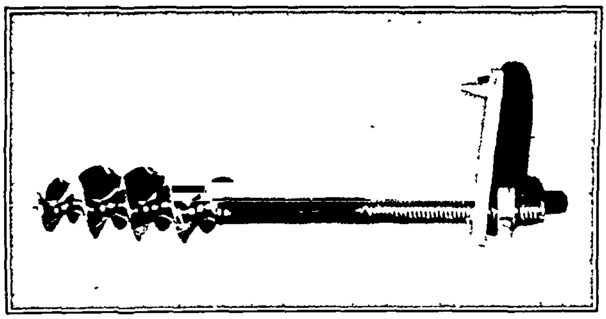

FIG. 1

Lippman screw, showing lock washer with spur.

Insertion of the screw into the largest depressed fragment is done gently with the ordinary hand drill, so that the fragment will not be broken. The screw grasps a large amount of intact cancellous bone on the side opposite the fracture. It is inserted through the largest fragment at the angle of maximum efficiency. This is determined by roentgenographic study and inspection at operation, at which time all fragments are reduced and held in the position of complete reduction by a blunt instrument. The screw is three and three-eighths inches in length, and the wide-thread, or corkscrew, element is three-eighths of an inch in diameter. These dimensions have been found to be adequate after study and measurement of many tibiae. The squared shank makes for ease of insertion with drills of different types, and is fitted with a large oval lock washer with a square hole, which cannot turn on the shank. The washer is fitted on the shank in such a position that the spur will be driven into intact bone, thereby locking the fractured fragments in three places. Next, the nut is tightened firmly onto the washer, thus giving fixation in three planes,—the sagittal, coronal, and lateral. The horizontal impaction is the most important, as it prevents possible separation of the fragments by rotary force, and produces transverse closure of the fracture line. The free end of the screw under the skin has not caused complications or discomfort.

Four cases have been selected, demonstrating different types of lesions and fixation with the vitallium lag screw.

CASE 1 is that of a simple comminuted fracture of the tibial condyle. The reduction and insertion of the screw was accomplished through *a very small incision directly over the fracture. In contrast to*

FIG. 2-A

FIG. 2-B

FIG. 2-C

FIG. 2-D

Case 1. Simple comminuted fracture of the lateral tibial condyle, not requiring removal of lateral cartilage.

Figs. 2-A and 2-B: Before reduction.

Figs. 2-C and 2-D: After reduction and insertion of screw.

what is usually required, it was not necessary in this case to make an incision into the knee joint proper. A minimum of upward impaction was needed; hence the screw was directed slightly upward and extended across the tibia, well past the fracture line, to grasp good bone. The patient was treated four years ago and has been asymptomatic during this time. The patient refused to have the screw removed.

CASE 2 presented a fracture of the posteromedial portion of the tibial plateau. It was necessary to start the screw from a slightly posterior angle in order to re-establish the horizontal plane. This screw was directed upward slightly to prevent subsequent depression while healing, in order to effect the transverse impaction and to overcome the rotary force. One year after removal of the screw, excellent painless stability was present, and no arthritis had developed in the joints. During this period the patient was on military duty, which necessitated a great deal of walking and required a painless, stable knee.

CASE 3 was one of extensive comminution and avulsion of the tibial spine, which had caused the knee to be locked in flexion. It was necessary to open the knee joint, exposing the entire fracture. The medial cartilage was badly torn and had to be removed. The tibial spine was replaced in its normal position. The plateau fracture was reduced with a periosteal elevator, and held in place by direct pressure and abduction of the leg. The screw was inserted through the largest fragment to the opposite side of the tibia in order to draw the fragments together. The nut was tightened over the lock washer after the spur had been forced into intact bone.

CASE 4 was one of compound fracture of the lateral tibial plateau, which opened widely into the knee joint on the lateral side. The patient was first seen eighteen hours after the fracture had occurred. After débridement, including the removal of the lateral cartilage, of which the anterior three fourths was hanging free from the wound, it was evident that an accurate reduction and maintenance of the large tibial plateau fragment must be carried out, if any function of the joint was to be retained. The fragment would not stay in place without skeletal fixation. Hence, the screw was inserted and directed downward, since the remaining portion of the lateral collateral ligament kept drawing it out of its proper position. The lock washer was turned so as to lock the spur in the bone anteriorly, in order to prevent depression of the tibial plateau during the early absorptive period of bony union. The wound was left open after suture of the synovial membrane. Penicillin was used in the joint and consequently no infection resulted. The screw was removed in twelve weeks. Only one dressing was performed in eight weeks, when the cast was changed.

All patients were placed in casts from the upper thigh to the toes, with the knee in 25 degrees of flexion. The patient with compound fracture was placed in a hip spica cast, because he had also a compound fracture at the juncture of the pubic and ischial spine.

Accurate reduction and internal fixation are demonstrated in these four cases. They include the simple fracture, the comminuted fracture which involves most of the joint with the tibial spine, and the severe compound fracture with avulsion of the tibial condyle. Damage to the meniscus is often present, requiring its removal at the time of the reduction and internal fixation. In those instances in which the ligamentous tear is not too severe and the cartilage is not torn, however, the cartilage can be preserved, and has been demonstrated by roentgenogram to be present and intact a year after solid bony union has taken place. Accurate reduction and healing without deformity of the knee produce a normal weight-bearing line, and the secondary hypertrophic post-traumatic arthritic changes that invariably follow the malunion of condylar fractures are either prevented or certainly reduced in amount.

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ALLERGY OF JOINTS

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The most common and the best-known type of allergic involvement of the joints is that seen in serum sickness and in drug allergy. The manifestations include stiffness swelling, redness, and pain in the joints. There is evidence of local oedema, resulting in exudation of fluid. The reaction usually lasts for only a short time.

As early as 1895, Osler brought out the fact that a certain percentage of patients suffering from Henoch's purpura present transient recurrent articular manifestations. These patients show a variable combination of the following symptoms: (1) skin findings, such as purpura, urticaria, and angioneurotic oedema; (2) abdominal symptoms (colic, diarrhoea, and gastro-intestinal hemorrhages); and (3) involvement of the joints, due to periarticular and intra-articular oedema and effusion. Osler reported eleven instances of Henoch's purpura; five of these patients had articular symptoms. In one, the swollen painful joints and purpura followed the injection of iodoform into the hip joint; this could have been due to a sensitivity to the drug. Osler collected fifty cases of Henoch's purpura from the literature, thirty-two of which presented some form of "arthritis", due to an effusion in the tendon sheaths along the joints. In 1914, he cited several additional cases of the same condition, and mentioned the possibility that this condition might be due to protein sensitivity.

Alexander and Eyermann reported four cases of Henoch's purpura. All of their patients had gastro-intestinal and abdominal symptoms; one had urticaria, three had purpura, and two had arthritic manifestations. All of the patients showed unmistakable clinical evidence of food sensitivity. In 1929, the same authors presented six more cases of clinical food sensitivity, which produced the various manifestations of Henoch's purpura. These reports on Henoch's purpura are cited here because the recurrent joint manifestations are a prominent symptom in this condition, and, furthermore, because there is evidence that allergy to foods plays an important role in their production.

There are in the literature, however, other references to recurrent, transient articular involvement, occurring without serum sickness, drug allergy, or Henoch's purpura, which

are caused by allergy to food. Among these may be mentioned the reports by Bolton, Bezançon and his associates, Turnbull, Adelsberger and Munter, Lewin and Taub, Service, and Berger. For the most part, they include symptoms of intermittent swelling and pain in the joints, resulting from the ingestion of certain foods, particularly fish, nuts, and eggs. Sometimes the condition was associated with other allergic manifestations,—usually urticaria and angioneurotic oedema.

The purpose of this paper is to call attention again to the possibility that intermittent swelling of various joints in the body may occasionally be of allergic origin.

CASE REPORTS

CASE 1. I. D., a female, aged forty, gave a history of paroxysms of excruciating pain in the back of the neck, radiating down to the right shoulder and the right arm. This condition had been present, off and on, for five months. Accompanying the pain, there was some swelling of the right shoulder and the right upper arm. The patient found it difficult to turn her head in either direction During the attack, motion and physical activity always aggravated the symptoms At other times the pain would come on suddenly, without apparent provocation, even waking her in the middle of the night Because of the frequent nocturnal occurrence of the pain and consequent loss of sleep, the patient became quite irritable and lost a great deal of weight. Several months after the onset of the pain, because symptomatic treatment did not give relief, she was hospitalized for a complete investigation At this time the physical examination was entirely negative, except for some tenderness over the entire trapezius and deltoid muscles, and over the spinous processes of the mid-cervical and lower cervical vertebrae. Mild muscle spasm could be palpated over the right shoulder and arm. Roentgenograms of the entire cervical and thoracic spine were negative. The urine was negative. The blood count, sedimentation rate, blood chemistry, and serology were normal. The eosinophil count was 9 per cent. The patient was studied by an internist, an orthopaedic surgeon, and a neuropsychiatrist Because of marked emotional manifestations, without any positive objective data, she was discharged from the hospital with a diagnosis of functional neurosis.

The condition had become increasingly worse when the patient was seen on November 3, 1943. In addition to the history stated above, she also complained of intermittent swelling and pain of the middle finger of the right hand. This joint presented a fusiform swelling, without marked redness or heat. The swelling was accompanied by definite limitation of motion. Roentgenograms showed no pathological changes in the joint. All laboratory tests were negative.

The patient had been seen on previous occasions She reported in July 1930, complaining of indefinite gastric symptoms and occasional pain in the region of the thoracic vertebrae. There was local tenderness over the thoracic spinous processes. The pain was aggravated by motion Two years later she was seen at home because of severe and intractable generalized urticaria, which covered practically the entire body. On another occasion a marked contact dermatitis developed after she had worn a black chiffon-taffeta dress. She found repeatedly that the ingestion of chili sauce or tomatoes produced generalized hives.

The patient was seen again in April 1938. Following a course of emmenin, urticaria and marked swelling of the right knee and right ankle developed The emmenin was discontinued and the joint condition disappeared, only to return with resumption of treatment There was no family history of allergy, and no history of associated allergic manifestations

Because of the past history, it seemed possible that the patient's present intermittent condition, involving the cervical vertebrae and the joints of the middle finger of the right hand, might be allergic. Positive skin reactions were obtained to many foods. She was found to be sensitive clinically to tomatoes, chili sauce, fish, and grapes, although no skin reaction could be obtained from the grapes On several occasions the patient experienced joint symptoms after eating grapes or drinking grape wine. Withdrawing these foods from her diet brought about complete disappearance of her symptoms.

CASE 2. R. H, a male, aged thirty-seven, was seen in April 1941, when he complained of intermittent pain and swelling of the right great toe This was occasionally associated with swelling and pain of the right ankle. The joints were not tender. The skin was tense and burning and, after the swelling had disappeared, the skin scaled. At times the swelling had been so marked that the patient could not put on his shoe. He stated that he had previously had a similar condition in his right knee, and at that time he had found it difficult to drive his car. The patient received treatment for arthritis and was confined to bed for a period of six weeks. Arch supports and other orthopaedic treatment did not give relief. The patient stated that he had had moderate hives two or three times, and that on at least one occasion he had had massive swelling of one eye. There was a family history of asthma

The physical examination was entirely negative. No involvement of the ankles, toes, or any of the other joints was evident. Several weeks later, however, there was marked swelling of the great toe of the left foot. There was no redness and only slight tenderness over the affected joint. The skin was tense and drawn. The patient had extreme pain on motion and had spent several sleepless nights. Roentgenograms of the involved joint showed no pathological changes. The blood count, sedimentation rate, serology, and blood chemistry were normal.

Because of the history of hives and the lack of evidence of acute arthritis, it was decided to study the patient from an allergic viewpoint. Skin tests showed positive intradermal reactions to a great many foods, especially to nuts. In order to determine the specificity of these positive intradermal reactions, passive transfer tests were carried out. The test consists of transferring a small amount of the patient's serum (0.1 cubic centimeter) intradermally to the skin of a normal, non-allergic person. Each sensitized area was tested six to twelve hours later with an extract of almonds and peanuts. Both passive transfer tests were positive, indicating that the patient's serum contained skin-sensitizing antibodies (reagins) against peanuts and almonds. The patient recalled that on several occasions the ingestion of peanut butter produced generalized urticaria. Elimination of all nuts from his diet gave complete relief from the symptoms. The ingestion of nuts or of wheat invariably brought on a paroxysm of urticaria or some joint swelling and pain.

Case 3. The patient was a twelve-year-old girl who was first seen in 1942, when she complained of intermittent swelling of the right ankle and the left wrist. The joints became swollen without any apparent cause and the swelling persisted for a period of several hours, or at times for several days, during which she could not move her foot or hand without severe pain. The swelling was not accompanied by fever or by increased local heat or redness. There was no history of involvement of the other joints. There was no history of growing pains, acute rheumatic fever, chorea, or any other rheumatic infection. The tonsils had been enucleated when the patient was five years old. The patient had had several attacks of urticaria some years before. She had had an intolerance for eggs for many years; the ingestion of even a small quantity of egg would produce generalized urticaria. There was no family history of allergy.

At the time of the first examination, there appeared to be no articular involvement. The physical examination was entirely negative, except for a systolic murmur which was not transmitted. An electrocardiogram and a roentgenogram of the heart were normal. The sedimentation rate was normal. The blood examination showed an eosinophilia of 10 per cent.

The absence of fever and of signs of local inflammation, the normal sedimentation rate, normal roentgenogram, and positive allergic history suggested the possibility that this might be a case of angioneurotic oedema, which from time to time involved various joints. The patient showed a marked positive reaction by direct skin test to eggs and to several other foods. A small quantity of egg albumen by mouth gave rise to urticaria. On only one occasion, however, did the ingestion of egg cause swelling of the right ankle. The patient was placed on a completely egg-free diet and has been entirely free of joint symptoms for the past two years.

Case 4. J. C., a male physician, aged sixty-five, was present at a medical meeting where the subject of allergy was being presented. After the meeting he cited his own experience, stating that he had had an allergy for a great many years. The patient had a family history of allergy. Paroxysmal attacks of blindness in one eye and intermittent swelling of several joints of his fingers occurred after the ingestion of fish. The joint or joints would become swollen, tender, and painful, and the condition would last from a few hours to a few days. The physical examination was otherwise negative. He stated that examination of the eyegrounds showed oedema of the macula in the affected eye during a paroxysm. The patient could always induce the swelling of his fingers by eating fish. Absolute avoidance of all fish and fish products gave complete relief.

COMMENT

Allergic arthropathies may be classified as follows:

The first group includes those instances of long-standing, chronic infectious arthritis which are thought to be due to bacterial allergy. Little is known about the allergic nature of this group and it is not included in this presentation.

In the second category is articular swelling resulting from sensitivity to a foreign serum or to a drug. This condition is usually transitory and is easily recognized as allergic, because it is a part of a generalized reaction to serum or drug.

The third group includes intermittent hydrarthrosis, which is a massive recurrent swelling of a joint, usually the knee. It is found more frequently in women than in men, and is accompanied by effusion of fluid into the joint.

In the fourth group are cases of Henoch's purpura associated with articular swelling and pain which, in some instances at least, might be due to allergy.

The fifth group comprises cases of acute transient paroxysmal articular involvement of joints, characterized by pain, swelling, and limitation of motion. Clinically, the cases simulate subacute arthritis, except for the absence of elevation of temperature, leukocytosis, increased sedimentation rate, and positive roentgenographic findings. This condition is transitory and recurrent and is associated with other allergic conditions, such as migraine, urticaria, angioneurotic oedema, asthma, and hay fever. Eosinophilia may be present. Positive skin tests may be elicited. The allergic nature of the condition is proved by clinical trial.

It is with this last type of joint involvement that this paper is concerned. The patient complains of excruciating pain which is migratory, sometimes involving the joints of the fingers, at other times involving the vertebral articulations or other joints of the body. At the time of the examination, nothing may be found and the patient may be labeled psychoneurotic, as in Case 1. On the other hand, the diagnosis of subacute or even of acute rheumatic fever may be made, and the patient may be confined to bed needlessly for a long period of time.

The mechanism of production of symptoms is probably the same as that in urticaria or angioneurotic oedema; the shock tissue is the synovial membrane of the joint, instead of the skin. Considerable, but transient, peri-articular oedema may occur, and at times there may even be a small amount of transudate into the joint cavity. This fluid may or may not be rich in eosinophils. The reaction, however, is reversible. The allergy is due to sensitivity to foods, and absolute elimination of these foods may result in complete relief.

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DEVELOPMENT OF SQUAMOUS-CELL CARCINOMATA IN THE SINUS TRACTS OF CHRONIC OSTEOMYELITIS

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Malignant degeneration of the skin which lines sinus tracts is not always readily recognized as a complication of chronic osteomyelitis. The carcinomatous lesions are in some instances large, cauliflower-like epitheliomata extruding from the sinuses; however, the more insidious variety, often unsuspected until the development of metastases, exists deep in the epithelialized cavities. Stewart, Obermayer, and Woolhandler reported a case in which skin metastases occurred, following the amputation of a thumb for chronic osteomyelitis. The pathologist's examination of the amputated phalanx then revealed the primary epithelioma.

Early recognition of malignant changes is often obscured by the primary pyogenic process. Most lesions exist for some time before their true nature is discovered. The purpose of the present paper is to point out the clinical and roentgenographic signs of this disease.

Henderson and Swart reported on five patients with malignant lesions among 2,396 cases of chronic osteomyelitis. Benedict found twelve such cases among 2,400 patients afflicted with chronic osteomyelitis. The epithelialization of draining sinuses in cancellous bone is well recognized. Milgram claims this to be one cause of persistent drainage.

Bereston and Ney, in reviewing the literature, found that malignant changes most often develop in males between the ages of forty and sixty years, who have had draining sinuses of from twenty to fifty years' duration. The tibia, the femur, and the bones of the foot are most often involved.

Hellner emphasized that increased pain, increased foul discharge, and bleeding from a sinus are indicative of malignant changes in chronic osteomyelitis. A pathological fracture in the infected area should also arouse suspicion. The discharge of small, white, cheesy masses, composed of desquamated, keratinized epithelium, is sound evidence that the sinus is well epithelialized.

Roentgenographic studies are not characteristic, so long as the malignant lesion is limited to the skin lining the sinus. Roentgenograms of the two cases to be presented, however, show many small areas of rarefaction in the sclerotic bone surrounding the sinuses. Hellner described similar roentgenograms in his cases of chronic osteomyelitis complicated by squamous-cell carcinoma, and he thought this to be characteristic of malignant invasion of the bone.

The positive diagnosis is made by performing a biopsy of material from the sinus tract. Curettage is not sufficient, since the lesion may be missed. Furthermore, when the material for biopsy is obtained by a superficial curettage, the pathologist may be unable to distinguish between a carcinoma and inflammatory changes. Therefore, the biopsy is best done in the operating room with the lesion fully exposed; several sections, thick enough to include the subcutaneous tissue, should be excised. Quick frozen sections are of little value, since a positive diagnosis usually can be made only when the lesion is grossly an obvious carcinoma.

Most authors report that the carcinomata associated with draining sinuses are well-differentiated, squamous-cell epitheliomata. That they show little tendency to metastasize has been pointed out by Bereston and Ney, who found only four cases in the literature and added two cases of their own in which visceral metastases were present. Metastasis to the lymph nodes may occur, but in most instances enlarged nodes are inflammatory and subside after amputation.

FIG. 1-A

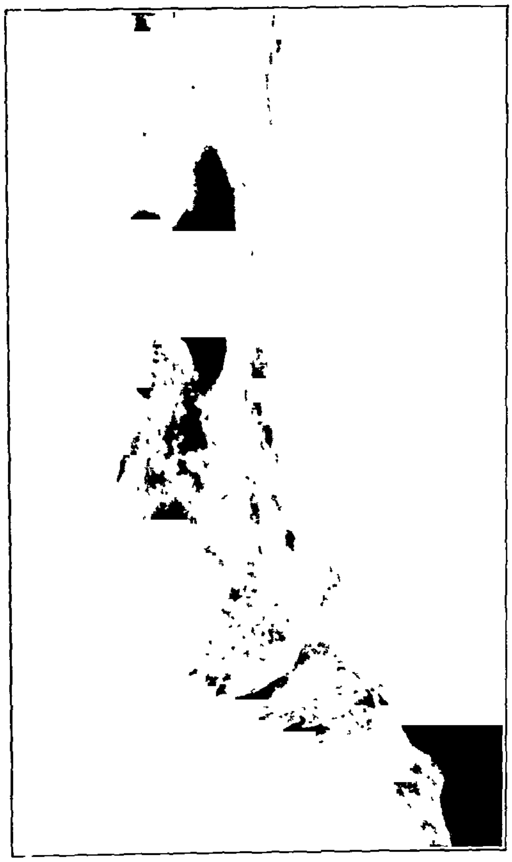

FIG. 1-B

Case 1, F. T. Anteroposterior and lateral roentgenograms of lower third of femur, demonstrating extensive destruction of the shaft and small irregular areas of rarefaction in cortex surrounding the large abscess cavity.

Amputation is usually the best method of treatment. Because of the existing infection, it is logical to perform a guillotine amputation as close to the involved area as may be done with safety. If enlarged lymph nodes are present and do not subside after the amputation, they should be excised, since they may contain metastatic carcinoma. Roentgenotherapy may then be initiated. The prognosis following amputation is good, since there are few early metastatic lesions.

CASE REPORTS

CASE 1. F. T., a white laborer, sixty-seven years of age, entered Stanford University Hospitals in February 1939, complaining of increased pain, foul discharge, and bleeding from the sinuses in his right thigh of eight months' duration. For sixty years he had had chronic osteomyelitis of the femur. Examination revealed a pathological fracture. On the medial and lateral sides of the middle third of the thigh were foul, discharging, epithelialized sinuses, which extended from large cavities deep within the bone. On the medial side, an abscess of the soft tissue extended up the thigh. Malignant changes were not suspected. A roentgenogram of the femur demonstrated an extensive osteomyelitic process, involving the distal half of the bone (Figs. 1-A and 1-B). Multiple small areas of destruction were noted in the sclerotic bone surrounding a large cavity in the femur. Several small sequestra were identified.

A pathological fracture, combined with the extensive destruction, necessitated drastic treatment. Accordingly, a guillotine amputation was done above the lesion. The stump healed well, except for a firm mass of what appeared to be granulation tissue; on pressure, this exuded caseous material. The mass was excised, and on microscopic examination it was found to be a squamous-cell carcinoma of a well-differentiated variety. Further examination of tissue from the sinus tracts of the amputated leg

FIG. 2-A

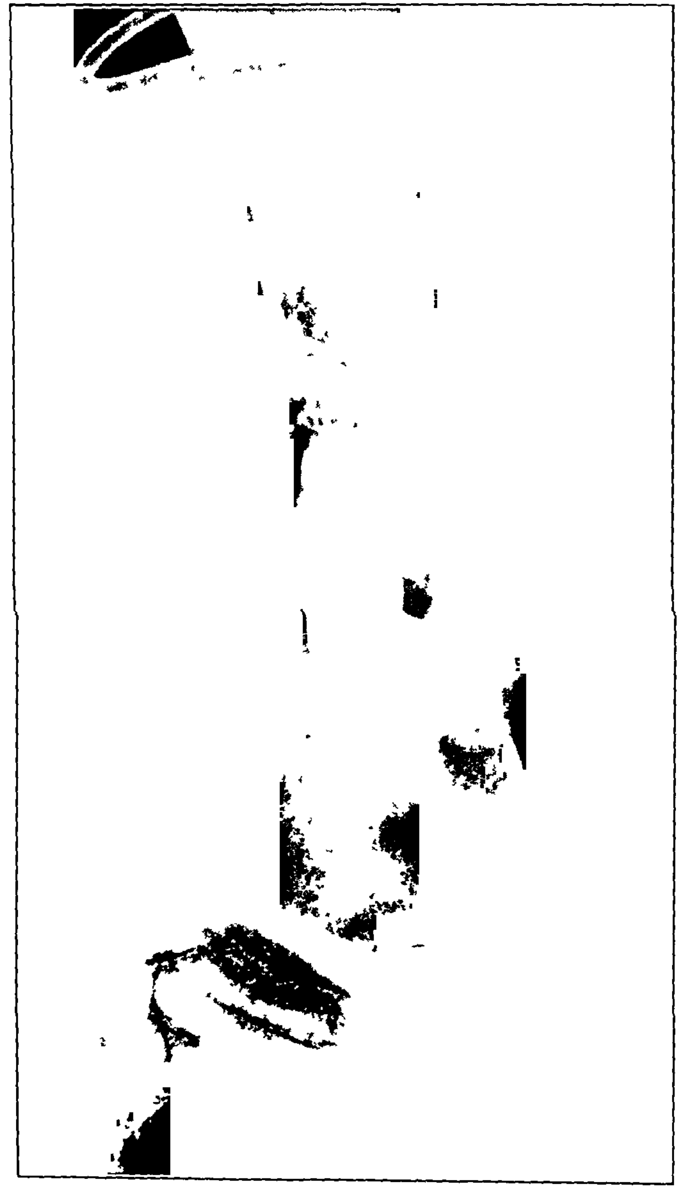

FIG. 2-B

Case 2, H. T. Anteroposterior and lateral roentgenograms of lower third of femur. Small areas of rarefaction are present in the sclerotic bone surrounding the large abscess cavity.

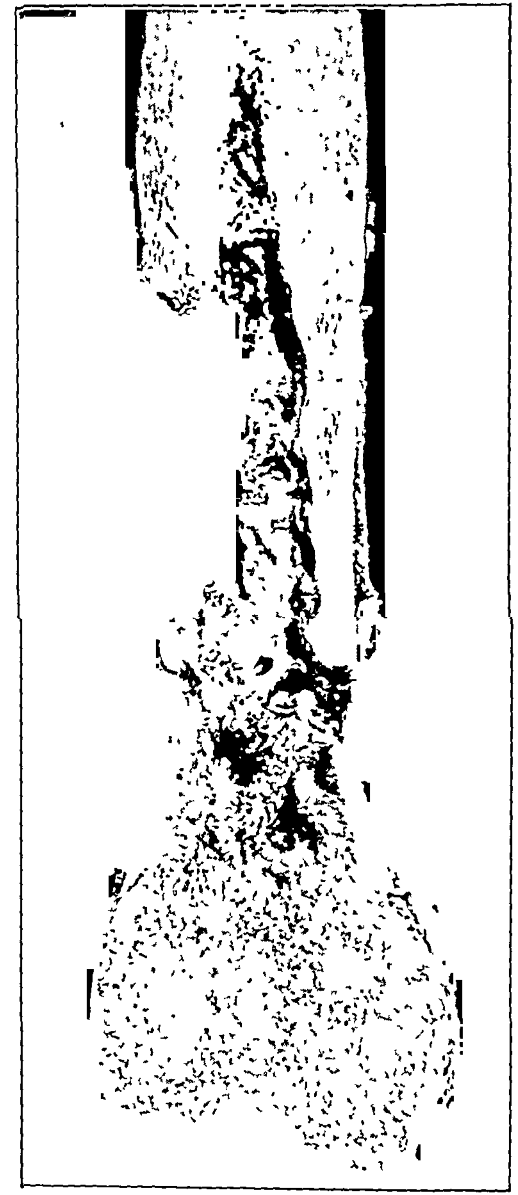

FIG. 2-C

Lateral section of femur, demonstrating

Fig. 2-D

Photomicrograph, demonstrating well-differentiated squamous-cell carcinoma.

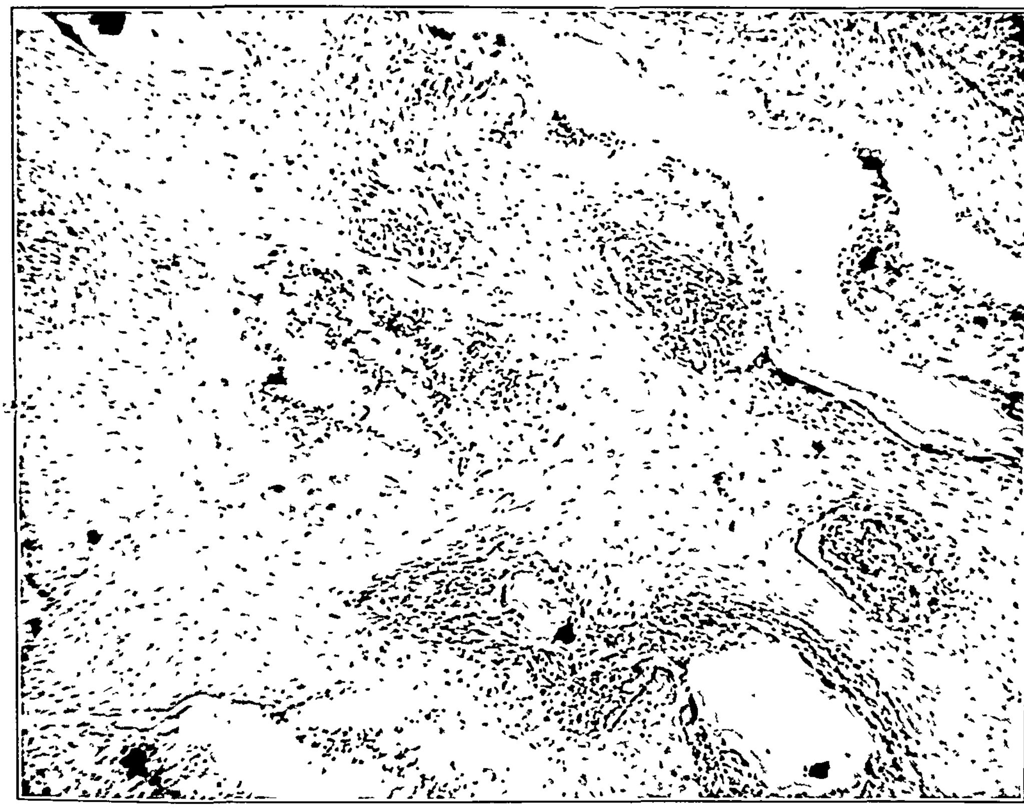

Fig. 2-E

Photomicrograph, demonstrating squamous-cell carcinoma surrounding dead bone.

disclosed the primary epithelioma. The amputation wound healed, and the patient is in good health at the present time.

CASE 2. H. T., a white business man, aged fifty-three, entered Stanford University Hospitals on November 25, 1944, with a draining sinus in his left thigh, which had been present for thirty-eight years. Many operations had resulted in only sporadic improvement. The patient walked well until three months before admission to the Hospital, when pain in the thigh caused him to use a cane. Since then the pain had increased and, in spite of chemotherapy, the discharge from the sinus became profuse and foul.

On the lateral side of the middle third of the left thigh there was a sinus, six inches long and three-quarters of an inch wide, which extended deep into the thickened, irregular femur. The skin grew evenly into the ostium around all of its edges. A profuse, putrid discharge, which contained firm, grayish, irregular particles, one to two millimeters in diameter, drained from the sinus. Three discrete, smooth lymph nodes and several smaller nodes were palpable in the left inguinal region.

Roentgenograms showed a large area of destruction in the shaft of the femur. The thickened cortex around this cavity was irregular and contained many small areas of destruction. On the medial side of the femur there was an abscess cavity, containing small sequestra (Figs. 2-A and 2-B). Roentgenograms taken of the same area, in 1934, demonstrated the large cavity; however, the femur surrounding the cavity was less irregular and the multiple small areas of destruction characteristic of the patient's recent roentgenograms were not present at that time.

Because of the changes noted in the roentgenograms, the increased pain, and the foul discharge from this obviously epithelialized sinus, a malignant lesion was suspected. The sinus was curetted. Although microscopic examination of the tissue obtained showed only chronic inflammation, it still seemed possible that a carcinoma might be present deep within the sinus.

The patient was taken to the operating room where the sinus was widely incised, exposing a large cavity in the femur. This, for the most part, was lined with skin, from which projected hard, cauliflower-like masses in several places. The anterolateral cortex of the femur over the abscess cavity was found to consist of many small spicules of bone imbedded in granulation tissue and carcinomatous tissue (Fig. 2-C). The granulation tissue, skin, and papillomatous growths were covered by foul, grayish-green pus. Necrosis had occurred in small areas in some of the larger papillomatous masses. Pathological study of the tissue which had been removed demonstrated squamous-cell carcinoma of a well-differentiated variety (Figs. 2-D and 2-E).

On December 13 a guillotine amputation of the femur was performed, two and one-half inches proximal to the upper end of the cavity. Since the amputation was done close to the infected area, penicillin was administered before and after surgery. Skin traction was applied to the stump after the operation.

A plastic operation was done on the stump at a later date. The inguinal nodes decreased markedly in size. At present the patient is healthy and without evidence of metastatic lesions.

DISCUSSION

These two cases clearly illustrate several points in the diagnosis of squamous-cell carcinoma, arising from epithelialized, chronic sinuses of bone. Both patients were in the age group in which this complication is most often found. In neither patient was the correct diagnosis obvious on clinical examination. The skin at the edges of the sinuses appeared irritated from the constant drainage. Microscopic examination of the tissue first removed showed only chronic inflammation. In fact, in Case 1, an epithelioma on the unhealed amputation stump led to re-examination and the discovery of the tumor in the amputated portion. The specimen obtained by curettage in Case 2 showed no epithelioma Thus in suspected cases it is well for the surgeon to perform a biopsy under direct vision in the operating room and to select several suitable specimens for microscopic examination.

Both patients had tolerated their osteomyelitis well for many years. Their complaints of pain and profuse foul discharge were of several months' duration only. The first patient had a pathological fracture of the femur and bleeding from the sinuses in his thigh. These findings are characteristic of carcinoma, developing in an epithelialized osteomyelitic sinus tract.

Roentgenograms of these two patients, although not diagnostic in themselves, presented a provocative finding of small areas of destruction in the sclerotic bone surrounding

the cavities, a picture which may be the result of extension of the carcinoma, as demonstrated by Figure 2-C.

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FIXATION OF THE TRANSPLANTED TIBIAL TUBERCLE *

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For many years, transplantation of the tibial tubercle has been an accepted procedure for the correction of two main pathological conditions. It has been employed, first, to take up the slack of the quadriceps apparatus in patients with spastic paralysis, following partial neurolysis of the hamstrings; and second, to correct recurrent dislocation of the patella. This operative procedure has routinely promoted good results. In the former condition, distal transplantation, under considerable tension, promotes the optimum result; whereas in the latter condition, medial transplantation with only moderate distal fixation is best.

In both conditions, transplants have proved difficult to hold, even when transfixed with screws. This is particularly true in spastic paralysis, because of the undue tension necessary to overcome inherent increased muscle tone. In the past, the long screws necessary to anchor the transplant to the posterior cortex frequently bent; or the transplanted tubercle split and pulled away from the point of fixation. Washers placed beneath the screw heads produced better results.

Good postoperative stability was not secured, however, until plates were used, which extended below the area of defect into which the tubercle was placed. This permitted anchorage of the whole transplanted area to solid tibia. By the use of a three-holed plate, which permits two screws to pass through the transplanted tibial tubercle and the distal end of the plate to be anchored by a third screw to solid tibia, such factors as wandering or pulling loose of the tibial tubercle, and bending of screws, have been eliminated.

At operation, with the incision wide open, the knee can be completely flexed passively without producing the least motion in the transplanted tubercle mass, even in patients with spastic paralysis where massive tension is present. Three screws are necessary. Two pass through the transplanted tubercle mass to prevent its rotation, as well as to hold it tightly in its new bed; the third screw is placed distally to anchor the other two screws and to prevent them from being bent by tension of the quadriceps. Figures 1-A, 1-B, 1-C, and 1-D show the gradual evolution of the present method of fixation and the rationale of the present procedure.

* Presented before the New York Academy of Medicine, Orthopaedic Section, November 17, 1944.

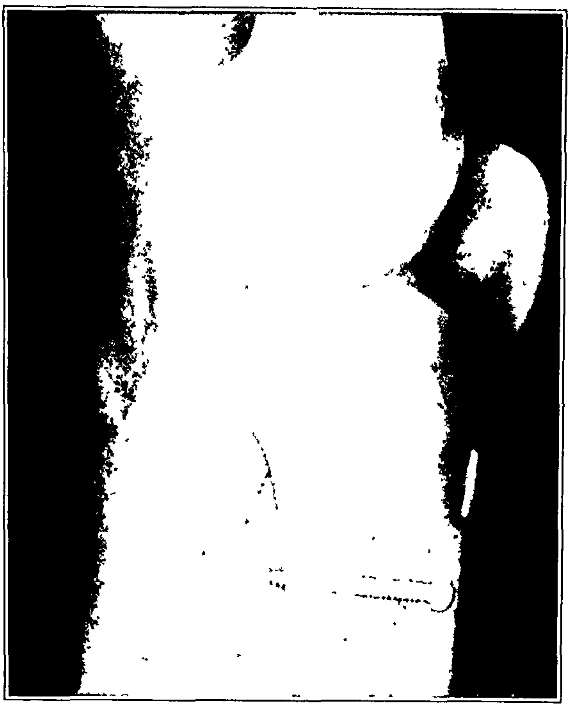

FIG. 1-A

FIG. 1-B

Fig. 1-A: Tibial tubercle is held in position with a single vitallium screw. Note that rotation of the tubercle has occurred and accurate maintenance of position is poor.

Fig. 1-B: Transplanted tubercle is held more satisfactorily with two vitallium screws. Here, as in Fig. 1-A, the bone which had been removed from the new defect in the tibia was replaced at the location from which the tibial tubercle had previously been removed. This is unnecessary.

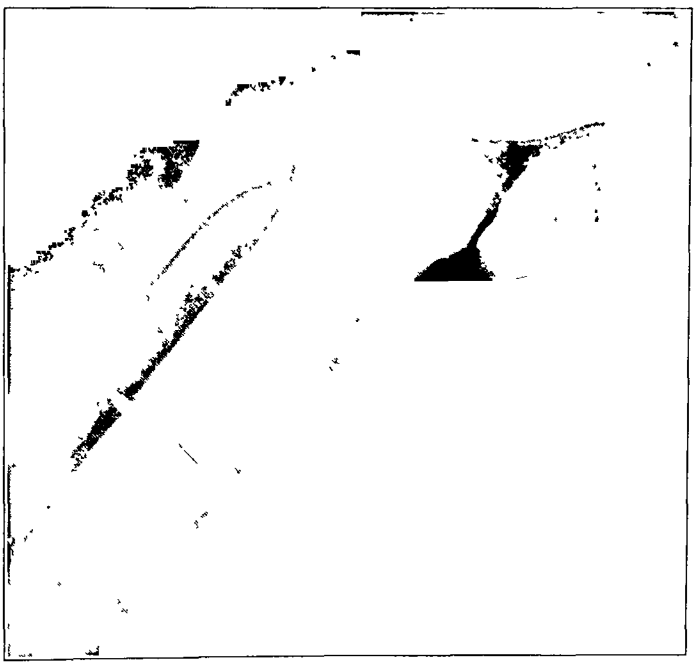

FIG. 1-C

FIG. 1-D

Fig. 1-C: Tubercle was transplanted too far distally, drawing down patella and later causing residual loss of flexion of the knee joint. Note single screw through transplanted tubercle. Distal screw anchors plate to solid bone.

Fig. 1-D: Shows present method of fastening tibial tubercle with plate. Two screws pass through plate and tubercle and a distal screw is fastened in solid tibia. The plate projects beyond the transplanted tubercle.

In transplantation of the tibial tubercle for recurrent dislocation of the patella, it is extremely important not to place the tubercle too far distally, but to gain all the medial displacement possible (Figs. 2-A, 2-B, and 2-C). The fixation with a plate and three screws remains the same. Support by a cylindrical plaster cast is necessary for one week after fixation.

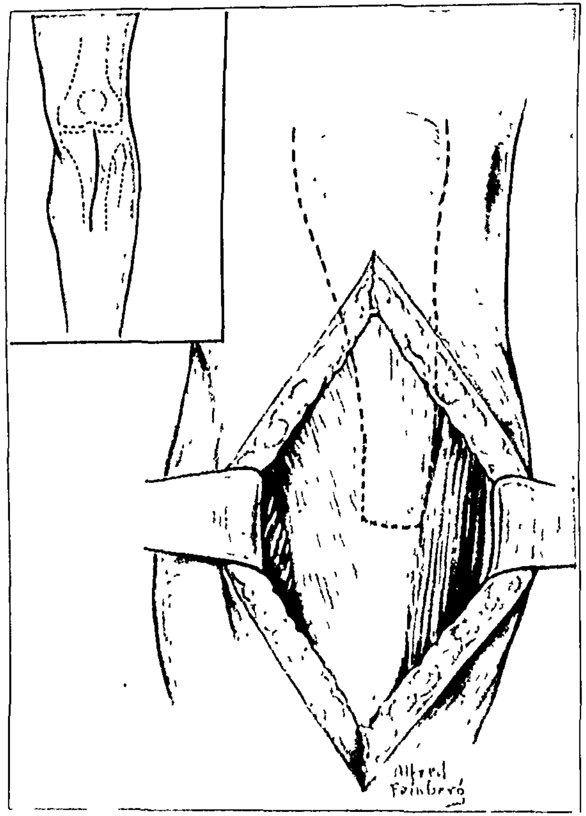

FIG. 2-A

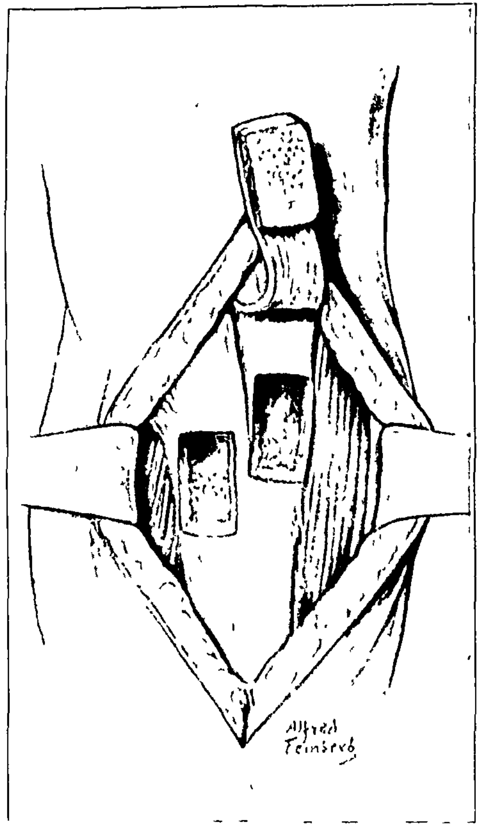

FIG. 2-B

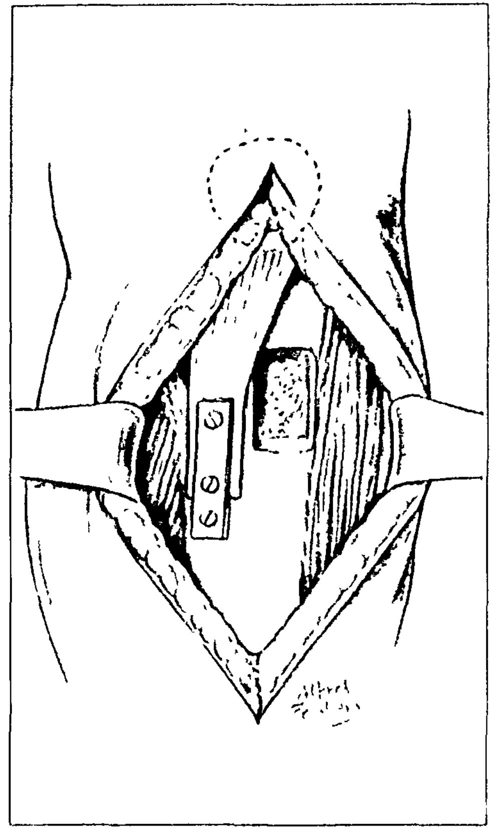

FIG. 2-C

Fig. 2-A: Area of incision is shown in inset. Illustrates dissection of soft parts, preparatory to actual operative work. Outline of incision about tibial tubercle and through medial and lateral capsule is indicated by dotted lines.

Fig. 2-B: Capsule has been incised, tibial tubercle has been turned upward, and a new defect in medial tibial surface at distal level has been created for reception of the transplanted tibial tubercle.

Fig. 2-C: Shows final transplant of tibial tubercle downward. Tubercle is maintained in transplanted position with plate, which extends downward over unbroken tibial surface. Coaptation of tubercle with defect is maintained with two screws. Stability of the whole is reinforced by distal screw, placed in solid tibia below.

BIOCHEMICAL CHANGES IN THE FRACTURE HEMATOMA

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The morphological changes in fracture repair have been studied extensively, and recently they have been completely reviewed in a series of papers by Urist and McLean. In the early stages of fracture repair, these changes at the site of fracture are similar to the repair processes in other tissues. At first there is an acute, inflammatory reaction, produced by the trauma causing the fracture. A hematoma of variable size forms at the break in the bone, and within a few days the process of repair begins, with organization of the hematoma by the ingrowth of fibroblasts and capillaries. After from seven to fifteen days, a unique change appears in the healing fracture, which distinguishes the process from repair in other parts of the body. A homogeneous material appears between the cells of the procallus. Whether the deposition of this osteoid material may be attributed to specialized fibroblasts, or whether there is actually an ingrowth of osteoblasts from the bone or the periosteum, cannot be finally determined. The formation of actual bone can occur without relation to bone or to periosteum, as Huggins demonstrated by transplanting the mucosa of the urinary bladder onto the rectus abdominis muscle of a dog. In any event, within from ten to fifteen days there is beginning calcification at the break in the bone, and new-bone formation proceeds to bridge the fracture.

Although the morphological changes which occur in fracture repair are well known, there is incomplete knowledge of the biochemistry of calcification. Robison was the first to demonstrate alkaline phosphatase in bone and cartilage which were undergoing calcification, and to stress the relationship of this enzyme to calcification. However, alkaline phosphatase has been demonstrated in organs, such as the kidney, where calcification does not normally take place. It would seem, therefore, that this enzyme system alone, without other special conditions, is not responsible for calcification. Such facts prompted Robison to postulate that there was probably a double-enzyme system involved in calcification. In the first place, there is reasonable doubt that a suitable substrate is present at the site of calcification, upon which alkaline phosphatase can act and produce an increase in the inorganic phosphate. It is also known that the glycogen concentration is high in hypertrophic cartilage cells, and that the concentration falls rapidly as calcification takes place. Gutman and Gutman have claimed that the second enzyme system postulated by Robison is phosphorylase, and that its function in calcification is in utilizing glycogen and inorganic phosphate to form some suitable phosphoric ester for alkaline phosphatase to act upon. This double-enzyme system would be responsible for raising the concentration of inorganic phosphate so that the product of Ca^{++} and $PO_4^{\equiv}$ ions exceeded 3.3 by 10^{-6}, which is the solubility product of secondary calcium phosphate at the pH of blood.

The following experiments were carried out in an attempt to correlate the relationship of the pH, the alkaline phosphatase, and the inorganic phosphate at the site of fracture before and during calcification. The liquid hematoma at the fracture site affords a convenient fluid, which can be aspirated and subjected to chemical analysis. Determinations of the pH, the alkaline phosphatase, and the inorganic phosphorus can be carried out on the hematoma fluid, and thus some idea of the biochemical changes which occur in the healing fracture can be obtained. The hematoma fluid does not give an absolute representation of the biochemical process in fracture healing. It probably reflects these changes to a certain extent, however, and should give some indication of the major changes going on during the early stages of fracture repair.

* Formerly Arthur Tracy Cabot Fellow.

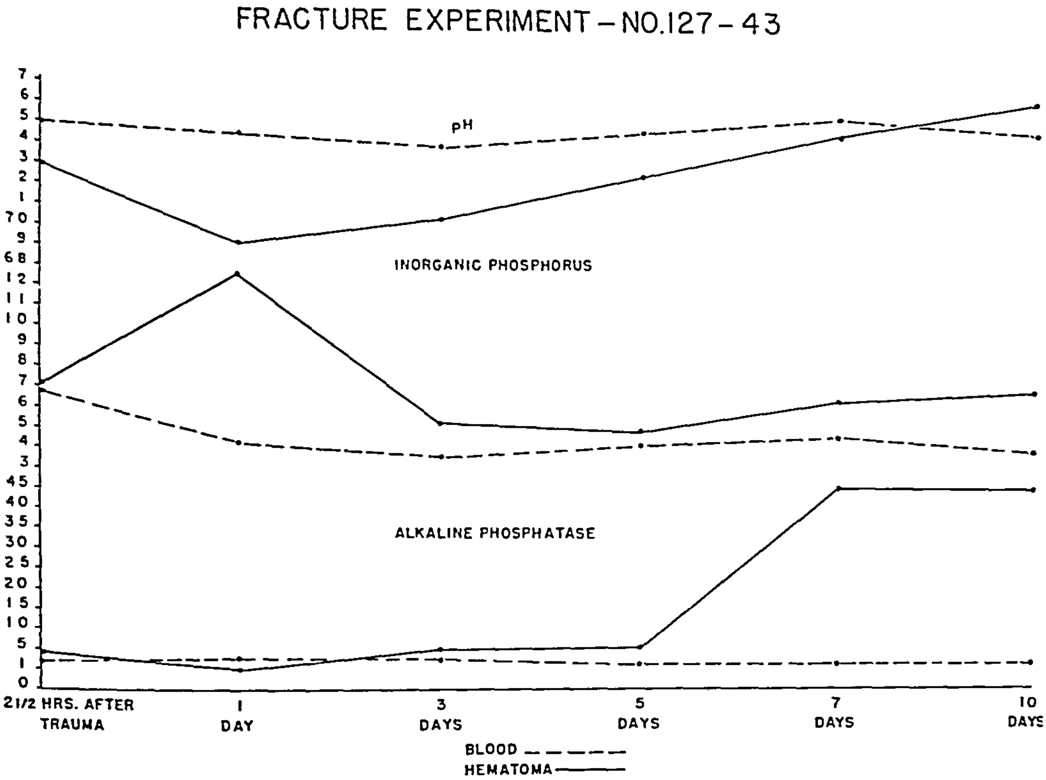

CHART I

METHODS

The operative technique consisted of aseptic exposure of the canine femur and elevation of a full-thickness spicule of bone, with resection of a portion of the vastus lateralis. The fractures produced by this method had moderate-sized hematomata, which were readily aspirated. The routine for aspiration was as follows: Two and one-half hours after the fracture had been produced, the hematoma was aspirated; and determinations of the pH, the inorganic phosphorus, and the alkaline phosphatase were carried out. The aspiration was repeated in twenty-four hours and every forty-eight hours thereafter, as long as fluid could be obtained readily. The hydrogen-ion activity was determined by the use of a microglass electrode. Inorganic-phosphorus determinations were carried out by a modification of the method of Fiske and Subbarow, in which 0.1 milliliter of fluid was used for each determination. The phosphatase was determined in Bodansky units, using 0.1 milliliter of fluid for each determination. Specimens for biopsy were taken from the fracture site at various times in order to correlate the histological findings with the biochemical results. The sections were stained by the Kossa method to demonstrate calcification. A number of fractures were produced, but a high percentage were unsuitable for this experiment, either because of infection or because of limited hematomata, which failed to give a sufficient volume of fluid for the various determinations.

RESULTS

The pH values were, in general, similar to those reported by Stirling and by Murray. Two and one-half hours after the fracture, the hematoma fluid was more acid than the venous blood; this acidity became more pronounced in twenty-four hours, the lowest pH determination being 6.9 (Table I). In the course of the next ten days, the pH gradually shifted to the alkaline side; the highest reading was 7.6.

During the first twenty-four hours after the fracture had been produced, there was a

Comparative Determinations of pH, Inorganic Phosphorus, and Alkaline Phosphatase in Fracture Hematoma and in Venous Blood

Date		pH	Inorganic Phosphorus (*Milligrams per 100 c.c.*)	Alkaline Phosphatase (*Bodansky Units*)
Fracture No. 127–43				
Aug. 10, 1943	Hematoma*	7.3	7.0	3.0
	Blood	7.5	6.9	1.0
Aug. 11, 1943	Hematoma	6.9	12.0	1.0
	Blood	7.4	4.2	2.0
Aug. 13, 1943	Hematoma	7.0	5.2	4.8
	Blood	7.4	3.5	3.0
Aug. 15, 1943	Hematoma	7.2	4.4	4.7
	Blood	7.4	3.7	2.0
Aug. 17, 1943	Hematoma	7.4	6.0	45.0
	Blood	7.5	3.6	2.2
Aug. 19, 1943	Hematoma	7.6	6.8	45.0
	Blood	7.4	3.4	2.3
	Biopsy: Definite calcification			
Fracture No. 217–43				
Sept. 17, 1943	Hematoma*	7.42	5.6	4.9
	Blood	7.51	6.4	3.2
Sept. 18, 1943	Hematoma	7.33	5.3	4.7
	Blood	7.54	3.3	6.2
Sept. 20, 1943	Hematoma	7.26	6.6	3.5
	Blood	7.48	3.9	4.3
Sept. 22, 1943	Hematoma	7.28	4.7	2.7
	Blood	7.49	4.4	2.0
Sept. 24, 1943	Hematoma	7.29	4.3	11.2
	Blood	7.52	3.9	2.8
Sept. 25, 1943	Hematoma	7.51	7.4	44.0
	Blood	7.49	4.8	1.9
	Biopsy: Questionable calcification			

Date		pH	Inorganic Phosphorus (*Milligrams per 100 c.c.*)	Alkaline Phosphatase (*Bodansky Units*)
Fracture No. 220–43				
Sept. 8, 1943	Hematoma*	7.18	8.3	2.1
	Blood	7.35	6.0	4.6
Sept. 9, 1943	Hematoma	7.07	18.7	3.9
	Blood	7.48	4.1	6.1
Sept. 11, 1943	Hematoma	7.19	8.6	2.6
	Blood	7.52	4.1	2.8
Sept. 13, 1943	Hematoma	7.22	4.1	3.1
	Blood	7.56	3.2	2.4
Sept. 15, 1943	Hematoma	7.29	3.2	1.0
	Blood	7.58	3.7	1.0
Sept. 17, 1943	Hematoma	7.36	4.3	6.4
	Blood	7.54	4.8	4.8
Sept. 19, 1943	Hematoma	7.32	4.0	10.6
	Blood	7.54	3.3	5.0
Sept. 22, 1943	Hematoma	7.47	5.7	51.3
	Blood	7.49	3.9	5.4
Sept. 24, 1943	Hematoma	7.53	6.3	56.3
	Blood	7.47	3.9	5.5
	Biopsy: Definite calcification			
Fracture No. 235–43				
Sept. 27, 1943	Hematoma*	7.34	6.3	2.3
	Blood	7.49	4.8	4.8
Sept. 28, 1943	Hematoma	7.25	8.5	8.3
	Blood	7.49	5.1	8.2
Sept. 30, 1943	Hematoma	7.37	5.6	5.5
	Blood	7.55	4.4	6.7
Oct. 2, 1943	Hematoma	7.42	6.0	15.0
	Blood	7.44	4.6	5.7
Oct. 4, 1943	Hematoma	7.52	5.6	20.1
	Blood	7.45	4.1	8.1
	Biopsy: Questionable calcification			

* Two and one-half hours after fracture.

Fracture No. 215–43				
Oct. 11, 1943	Hematoma*	7.28	8.6	3.5
	Blood	7.45	6.1	4.4
Oct. 12, 1943	Hematoma	7.25	5.4	6.6
	Blood	7.48	4.3	5.3
Oct. 14, 1943	Hematoma	7.29	4.9	2.2
	Blood	7.42	4.9	6.1
Oct. 16, 1943	Hematoma	7.24	4.9	2.7
	Blood	7.41	4.9	2.7
Oct. 18, 1943	Hematoma	7.51	5.6	16.1
	Blood	7.49	5.1	3.9
Oct. 20, 1943	Hematoma	7.46	4.4	10.0
	Blood	7.44	3.9	3.5
	Biopsy: Definite calcification			
Fracture No. 333–43				
Dec. 17, 1943	Hematoma†	7.36	5.4	3.7
	Blood	7.49	4.0	4.9
Dec. 18, 1943	Hematoma	7.36	5.5	5.0
	Blood	7.39	4.3	3.5
Dec. 20, 1943	Hematoma	7.25	6.5	7.3
	Blood	7.35	4.7	3.2
Dec. 22, 1943	Hematoma	7.30	5.6	1.7
	Blood	7.40	4.3	3.0
Dec. 24, 1943	Hematoma	7.41	5.3	16.2
	Blood	7.41	3.7	1.4
Dec. 27, 1943	Hematoma	7.54	5.5	14.8
	Blood	7.36	4.8	4.3
	Biopsy: Definite calcification			
Fracture No. 309–43				
Nov. 19, 1943	Hematoma†	7.35	6.9	4.8
	Blood	7.48	5.9	3.6
Nov. 20, 1943	Hematoma	7.08	15.7	4.6
	Blood	7.42	4.9	4.8
Nov. 22, 1943	Hematoma	7.21	7.9	4.2
	Blood	7.41	5.1	3.7
Nov. 24, 1943	Hematoma	7.31	9.2	6.8
	Blood	7.41	7.1	5.6
Nov. 26, 1943	Hematoma	7.41	6.8	16.6
	Blood	7.38	4.9	7.4
	Biopsy: Definite calcification			
Fracture No. 3–44				
Jan. 5, 1944	Hematoma†	7.15	5.9	1.4
	Blood	7.33	2.6	2.4
Jan. 6, 1944	Hematoma	7.13	4.6	1.5
	Blood		2.9	2.6
Jan. 8, 1944	Hematoma	7.30	4.2	2.3
	Blood	7.46	3.4	1.1
Jan. 10, 1944	Hematoma	7.34	4.8	7.6
	Blood	7.39	3.8	2.0
Jan. 12, 1944	Hematoma	7.44	4.5	4.7
	Blood	7.44	4.2	1.9
Jan. 14, 1944	Hematoma	7.54	5.7	19.9
	Blood	7.45	4.4	3.2
	Biopsy: Definite calcification			

* Two and one-half hours after fracture.
† Three hours after fracture.

FIG. 1

Photomicrograph of section from Fracture No. 127–43, taken at the end of the experiment (ninth day). Section was stained for calcium by the Kossa technique; calcification is well demonstrated.

FIG. 2

Photomicrograph of section of tissue removed from Fracture No. 220–43 at the end of the experiment (fifteenth day). *Calcification is well demonstrated by the Kossa staining technique.*

marked increase in the inorganic-phosphorus level. This value was as high as 18.7 milligrams per 100 cubic centimeters for the hematoma fluid, whereas the circulating venous blood has a level of from three to four milligrams per 100 cubic centimeters. Within the

next forty-eight hours the inorganic-phosphorus level in the hematoma fluid had fallen to a concentration which approximated the level in the venous blood. The inorganic-phosphorus determination remained at about the same value in the hematoma fluid and in the venous blood until the seventh to tenth day, when there was an increase in the inorganic phosphorus in the hematoma fluid. At the end of the experiment, the value for the hematoma fluid was as high as 7.4 milligrams per 100 cubic centimeters, which was almost twice the level in the venous blood.

The alkaline phosphatase had a rather characteristic curve (Chart I). Soon after the fracture had been produced, the phosphatase level in the hematoma fluid was about the same as that in the circulating blood. or lower. It was maintained at about the same level as in the venous blood until the seventh to the fifteenth day, at which time there was a marked elevation in the phosphatase activity, with values as high as fifty-six Bodansky units.

In correlating these three determinations—that is, the pH, the inorganic phosphorus, and the alkaline phosphatase—it was found that, as the pH became alkaline, there was a marked increase in the amount of alkaline phosphatase and a moderate increase in the inorganic-phosphorus level in the hematoma fluid. Biopsies were made of the fracture material, and in six out of eight fractures there was definite calcification (Figs. 1 and 2). In the remaining two there was questionable calcification. There was no demonstrable calcification in a series of six fractures from which material for biopsy was obtained prior to these biochemical changes,—that is, before there was elevation in the alkaline phosphatase.

DISCUSSION

These experiments support the thesis that alkaline phosphatase is involved in the process of calcification, as seen in fracture repair. The experimental evidence would indicate that the phosphate-ion concentration is increased, at the site of calcification, by a complex enzyme mechanism in which alkaline phosphatase is involved. This is contrary to the theory of fracture healing proposed by such workers as Stirling and Murray. They postulate that the high local acidity at the fracture site produces an ideal medium for an increase of calcium, and that the subsequent change to local alkalinity in the fracture hematoma promotes precipitation of the calcium phosphates. No actual direct measurement of calcium concentration is reported to support this theory. The pH changes may affect the calcium-ion concentration in the fracture hematoma, but there are probably more decisive changes in the phosphate-ion concentration, which make possible a precipitation of some form of calcium phosphate.

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SARCOID OF BONE

Report of a Case

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CLINICAL FEATURES

Sarcoid of bone (also known as Jüngling's disease and Boeck's sarcoid) is seen most frequently in young adults, particularly in males. The onset is usually insidious. The bones of the hands and feet are most commonly affected, but cases have been reported which involved the long bones. There may be no external evidence of the disease, but usually there is irregular enlargement of the fingers or toes. Subcutaneous nodules may appear about the interphalangeal joints, and in advanced cases there may be gradual disappearance of the terminal phalanges. Pain may be present in the early stages, but it is never severe. The roentgenographic changes are so characteristic that they may be easily identified by anyone who is familiar with the disease.

Jüngling described three main roentgenographic pictures, although intermediate and mixed forms are common. Type 1 is a diffuse mottling or speckling of the affected bone, sometimes showing slight expansion of the cortex. Type 2 is characterized by a punched-out appearance, which gives the impression of translucent cysts in the substance of the bone. These cysts tend to fuse and to form larger cysts, but they seldom involve the periosteum or the joints. The punched-out areas, however, are not cystic in the true sense of the word, but contain semisolid granulation tissue—a fact which caused Jüngling to substitute the word *cystoïdes* (cystlike) for cystica in his second paper. Type 3 shows a loss of density and a latticework appearance (*Gitterstruktur*) in the substance of the bone, without any alteration of the contour.

PATHOLOGICAL CHARACTERISTICS

On pathological examination, the lesions appear as semisolid granulation tissue, characterized histologically by the presence of clumps of epithelioid cells, arranged in tubercle formation and surrounded by lymphocytes. Giant cells may be in evidence, but actual necrosis of tissue is not seen and the *Mycobacterium tuberculosis* cannot be demonstrated in the lesions. The constitutional reaction is seldom marked, and the blood picture is not characteristic. Salvesen observed an elevation of the level of total protein in the serum in three out of four cases of generalized sarcoidosis, but his observations have not been substantiated by others. Although the disease runs a chronic course, it exhibits a natural tendency to improvement, and over a period of years complete healing may take place.

ETIOLOGY

The origin of the group of lesions to which sarcoid of bone belongs is still obscure. Most writers have emphasized the resemblance to tuberculosis, but the *Mycobacterium tuberculosis* has seldom been found in the lesions and, when present, has been regarded as a purely incidental finding. The intradermal tuberculin reaction is usually negative, and Jadassohn has postulated a "positive anergy" for the disease. This hypothesis is supported in the report of a case by Schaumann, in which the patient contracted pulmonary tuberculosis of bovine origin, which led to the spontaneous disappearance of sarcoids of the skin, lymph nodes, and fingers. Lemming injected a large dose of living BCG vaccine into a typical case of uveoparotitis and caused a local reaction, with enlargement of the regional lymph nodes. In this case the Mantoux test remained negative, even after the injection of

five milligrams of old tuberculin; one of the nodes, which was excised for section, showed the characteristics of Boeck's sarcoid. Repeated injections of large doses of BCG vaccine into another patient with enlarged mediastinal nodes failed to alter the negative Mantoux test.

From this evidence, it is tempting to postulate that the causal organism of this group of diseases may be an attenuated strain of the *Mycobacterium tuberculosis*, but the difficulty of interpreting such findings comes to light when it is recalled that Sabin, Doan, and Forkner were able to produce a reaction in connective tissue, similar to that of sarcoid, by experimental injection of the phosphatide fraction A-3, derived from the lipoid envelope of the *Mycobacterium tuberculosis*. Murdock and Hutter state that the bony changes in the hands and feet closely simulate those of leprosy, but the *Mycobacterium leprae* has not been found in the lesions; and Pautrier reports that tissue inoculated into guinea pigs and Macacus monkeys has given negative results. In summary, although most observers regard the disease as an atypical form of tuberculosis, there is little direct evidence to support their contention.

DIFFERENTIAL DIAGNOSIS

The roentgenographic appearance is sufficiently characteristic to render the diagnosis of sarcoid of bone fairly simple. The few conditions with which it could be confused are as follows:

1. *Dactylitis Tuberculosa*: Dactylitis tuberculosa usually occurs in infants, whereas sarcoid of bone is seen in adults or adolescents. Dactylitis tuberculosa is associated with greater deformity of the bones and with necrosis; caseation and sinus formation are usually evident. The cutaneous tuberculin test is usually negative in sarcoid of bone, and *Mycobacterium tuberculosis* cannot be demonstrated in the tissues.

2. *Leprosy*: The lesions of leprosy are associated with severe destructive osteitis of the phalanges and irregularity of the interphalangeal joints. The nutrient foramina of the bones are unduly prominent in leprosy.

3. *Syphilis*: The diagnosis of syphilis can be established by means of serological reactions and by other evidences of the disease.

4. *Gout*: The diagnosis of gout is usually evident from the history, the blood chemistry, and the response to treatment.

5. *Traumatic Cysts*: Brailsford has described the occurrence of cysts in the carpal bones of men who have used compressed-air drills for ten years or more. In these cases the history of occupational exposure to prolonged trauma should be readily available.

TREATMENT

The question of specific therapy can be dismissed in three words: There is none. Arsenic, ultra-violet light, roentgen rays, and radium have all been tried, without benefit. Chaulmoogra oil has been used, because of the resemblance of the lesions to those of leprosy, but beneficial results have not been reported. It will be remembered that the disease shows a tendency to spontaneous improvement.

CASE REPORT

On February 8, 1945, F. W., aged twenty-four years, a gunner in the Royal Canadian Artillery, was admitted to Montreal Military Hospital, complaining of pain in the left wrist. He stated that he had been perfectly well until 1941, when he was driving a heavy army truck over a rutty road and the steering wheel suddenly "spun", twisting his left wrist. No roentgenograms were taken. The wrist remained painful for a week, and during that time he wore a simple bandage for support. After this accident he noticed that his left wrist was weak, and he experienced pain in the wrist when he lifted anything heavy or attempted to bear weight on the wrist. Two years before admission to the Hospital, a lump appeared on the volar surface of the wrist, but it did not increase appreciably in size. The wrist

FIG. 1

Roentgenogram of the left wrist. Note the cystlike areas in the lower end of the radius and in the carpal bones. Those in the metacarpals are not well demonstrated in this plate.

gradually became more painful, and shortly after D-day it began to be stiff. At that time the patient was on active service in France, and he was able to continue his regular duties without appreciable disability. In October 1944, an upper respiratory infection developed and he was admitted to a general hospital overseas. While there, roentgenograms were made of the left wrist. A cystic condition of the carpal bones was discovered, and the patient was repatriated to Canada.

The family history was non-contributory. The patient's father and mother were alive and well. Eight siblings were alive and well. One sister had died of pneumonia. There was no history of tuberculosis, cancer, or diabetes among the immediate relatives. The patient denied any serious illness in the past, and had never been subjected to surgical operation.

General physical examination was essentially negative. The patient appeared to be a healthy, vigorous, young adult male. The skin was healthy, there was no evidence of disease in the chest, nor any enlargement of the lymph nodes, liver, or spleen.

Examination of the left wrist showed a fluctuant, tender swelling, measuring about one centimeter in diameter, situated on the volar surface of the left wrist, just distal to the styloid process of the ulna. It was not attached to the skin, but seemed to arise from the deeper tissues, to which it was firmly adherent. There was no local heat or other sign of inflammatory reaction. There was no wasting of the left arm, but the grip of the left hand was less than normal. Dorsiflexion was limited by 15 degrees; palmar flexion was limited by 20 degrees and caused pain in the volar aspect of the wrist. Supination and pronation were full and painless. There was an area of acute tenderness to palpation over the scaphoid bone and over the mass, just distal to the ulnar styloid.

Roentgenograms of the left wrist, taken on February 2, 1945, showed small areas of bony destruction, cystlike in appearance, which formed punched-out lesions involving the triangular bone, the greater multangular, the capitate bone, the lower extremity of the radius, and the bases of the second and third metacarpals (Fig. 1). The joint spaces were free and there was no peculiarity of the soft tissues. The remainder of the skeleton was examined under the fluoroscope, but no other abnormalities were detected. Fluoroscopic examination of the chest was reported as negative.

The urinalysis was reported as negative. The blood examination was as follows:

Red blood cells	5,070,000
Hemoglobin	95 per cent.
White blood cells	9,050
Polymorphonuclear neutrophils	
Segmented	61 per cent.
Non-segmented	5 per cent.
Monocytes	4 per cent.
Lymphocytes	27 per cent.
Eosinophils	3 per cent.
Coagulation time	4 minutes and 23 seconds
Bleeding time	2 minutes and 33 seconds

The sedimentation rate was five millimeters per hour. The Wassermann reaction was negative.

On March 3, a biopsy was performed (by D.R.M.) on tissue from the swelling on the front of the

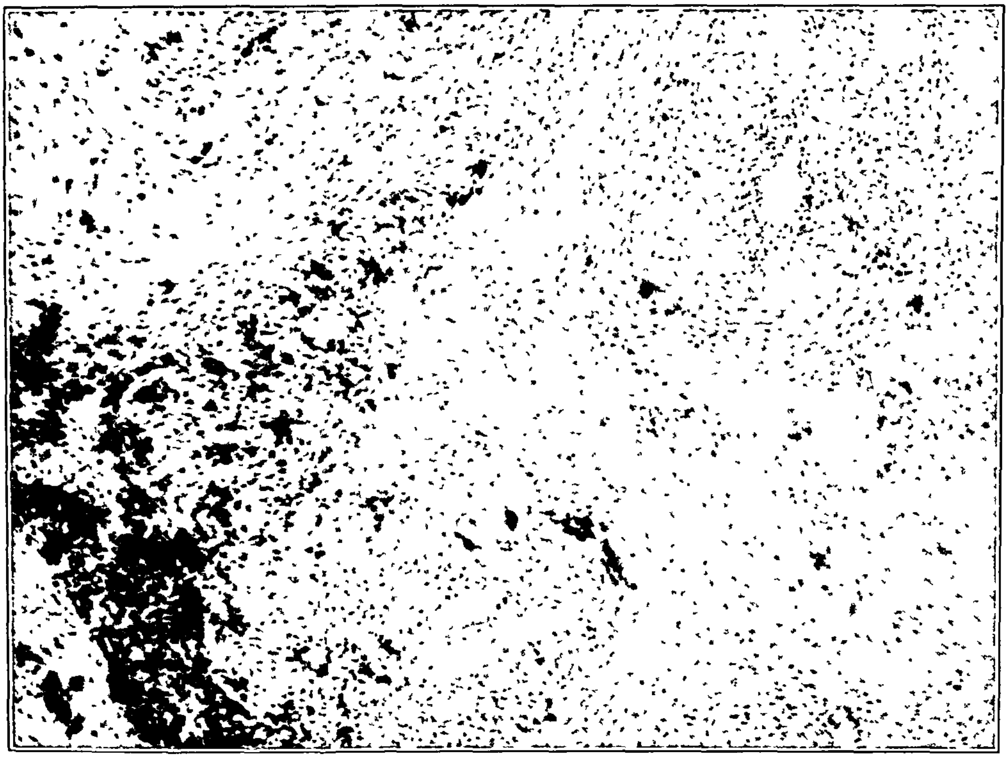

FIG. 2

Photomicrograph of excised tissue. Note islands of epithelioid cells, surrounded by lymphocytic infiltration. A giant cell is visible near the center of the field. There is no evidence of coagulation necrosis.

left wrist. The mass was found to consist of muddy, soft, yellowish granulation tissue. Histological examination was made, and all sections showed fibrous tissue in which there were focal areas of granulomatous inflammation. This expressed itself as clusters of epithelioid cells and occasional giant cells. The *Mycobacterium tuberculosis* was not seen in any of the sections. There was no coagulation necrosis (Fig. 2).

The wound which had been produced when tissue was removed for biopsy healed by first intention, and on March 29 the patient was discharged from the Hospital, to begin thirty days' disembarkation leave.

He was readmitted to Montreal Military Hospital on May 2, still complaining of slight pain in the left wrist. Examination showed that there had been no change in the power and movement of the wrist. The wound caused by removal of the tissue for biopsy was well healed. An intradermal tuberculin test was performed, using 0.5 milligram of old tuberculin; when read, forty-eight hours later, it gave a negative result. A roentgenographic examination, on May 4, showed both lung fields to be clear. There was some evidence of healing, especially at the lower end of the radius and in the scaphoid bone.

COMMENT

This case illustrates most of the points which Jüngling held to be characteristic of sarcoid of bone. The history of trauma to the wrist in 1941 was probably incidental, and it is doubtful whether it had any direct bearing on the development of the disease. Trauma has not been regarded of etiological significance by any of the authors who have written about the disease. In typical cases of sarcoid of bone, the bone lesions are predominantly in the metacarpal bones and phalanges of the hands and in the metatarsal bones and phalanges of the feet, but cyst formation in the bones of the carpus is well shown in one of the roentgenograms depicted in Jüngling's second paper. The insidious onset of the condition, and the relative absence of disability in the early stages, are brought out well when it is appreciated that this soldier sought no medical care for his wrist for a period of

four years, and was able to carry out the full duties of a gunner, even under the arduous conditions of the D-day landing on the coast of France, without apparent disability.

The roentgenographic picture of multiple cysts in the bones of the carpus, the metacarpals, and the bones of the forearm fits in well with Jüngling's Type 2 lesion. The tendency of the cysts to fuse and to form larger cysts is well borne out. Both macroscopically and microscopically, the biopsy specimen exhibited the lesions in typical form. The absence of caseation and the failure to demonstrate the *Mycobacterium tuberculosis* are both characteristic of the disease. Skin lesions and lymph-node enlargement, although frequently found in association with the osseous cysts, were not present in this case. The intradermal tuberculin test was negative, which is the usual finding in this disease. No specific treatment is known to have had any effect upon the disease.

The patient will be discharged from the Army and arrangements will be made for his return to civilian life. Meanwhile, the forearm and wrist will be immobilized in a plaster-of-Paris cast from the metacarpophalangeal joints to the fold of the elbow, with the wrist in the position of optimum function. The most recent roentgenograms showed more evidence of healing than those taken a month previously, and it is hoped that healing will be accelerated by placing the diseased part at rest.

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SPASMODIC TORTICOLLIS

Severe Organic Type Treated by Combined Operation, Rhizotomy, and Fusion *

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The term "spasmodic torticollis" is applied to a group of manifestations consisting of spasm of one or more muscles of the neck. These manifestations may result from emotional instability; from an organic lesion affecting the basal ganglia, peripheral nerves, or muscles; or from a combination of these factors. Not infrequently the discomfort and disability become so severe that surgical intervention is required.

Numerous surgical procedures have been employed, but, in extreme cases, extensive rhizotomy of the upper cervical nerves and section of the spinal accessory nerves become necessary. Occasionally, bilateral section of the upper three cervical nerves, combined with section of both spinal accessory nerves, results in subluxation of the upper cervical vertebrae which interferes with swallowing, breathing, and talking. When this occurs, a method of fixation to prevent the subluxation becomes necessary. The procedure outlined here has been employed to correct this deformity and to relieve spasm of the organic type.

ETIOLOGY

The etiology of the various types of spasmodic torticollis is not clearly defined, although it is agreed generally that two factors are responsible for the muscle spasm: (1) psychogenic or emotional imbalance (psychogenic or functional type) and (2) structural changes in the neuron system supplying the muscles affected (organic type). Rugh has stated that the psychogenic type is due to mental or physical stress in a neurotic person. The inherent instability of the nervous system, whether it be congenital or acquired, renders the nerve cells at the base of the brain especially susceptible to external stimuli from occupation or surroundings. He further stated that the cells are in a state of debility or exhaustion from overuse, which renders them susceptible to irritative and stimulative external conditions, but which is not followed by degenerative or pathological changes in the cells.

Spasmodic torticollis, resulting from structural change in the neurons to the affected muscles, may vary in character. Hyslop stated that torticollis of peripheral origin is due to a disorder in innervation. According to him, the defect may lie in the peripheral reflex arc and may be due to some form of inflammatory lesion, affecting either the muscle itself or the segments of the peripheral-nerve trunks supplying the muscle. Occasionally the spasm may be a compensatory reflex, such as occurs in certain types of extra-ocular paresis or imbalance. Instances have been described in which the stimulus which causes the muscle spasm apparently originates in the vestibular apparatus. Grinker made the statement, however, that the labyrinthine disturbance probably is due to a unilateral lesion of the brain stem. Rugh further stated, in a discussion of torticollis of central origin, that the torticollis represents the end result of stimuli. These stimuli may originate either in the cerebral cortex (which may be structurally perfectly healthy), or they may arise out of some structural or physiological alteration of function in the basal ganglia. He further observed that the severity of torticollis of central origin shares with certain other types of abnormal movements the tendency to vary with alterations in the patient's state of mind. He suggested that torticollis of central origin may be the result

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of certain primary infections of the nervous system. In particular, epidemic encephalitis is known to produce the symptoms. Alpers and Drayer found pathological changes in the large cells of the caudate nucleus and the putamen. It is generally agreed that, in the functional type of spasmodic torticollis, no changes occur in the affected muscles or fascia; whereas, in the organic type, pathological changes may occur. In dystonia following encephalitis, spasmodic torticollis may be only part of the clinical picture. Congenital torticollis is believed to be due to anomalous development, plus structural changes in the muscles characterized by contractures. The condition frequently referred to as wry-neck invariably is the result of myositis.

SYMPTOMS AND SIGNS

Spasmodic torticollis may involve one or more muscles of the neck, and the spasms may be tonic or clonic, or a combination of both. At the onset, the muscles on one side may be affected, but the condition may progress to involve the muscles on both sides. The muscles usually affected are those supplied by the spinal accessory nerves and the motor branches of the upper three cervical nerves. The sternocleidomastoid, the trapezius, and the splenius are the muscles which usually produce the deformities of which patients complain. When smaller muscles are affected, the abnormal positions of the head are less pronounced. Unilateral spasm of the sternocleidomastoid and trapezius muscles results in rotation of the chin to the opposite side, in an upward and outward direction. When the splenius muscle is involved on one side, the head is retracted posteriorly and to the same side. When the muscles on both sides are involved, the chin may first be tilted in one direction and then in the other. One side is usually affected more severely than the other. In the organic type, the spasms are more tonic than clonic. Pain is a frequent and severe symptom in the advanced stages. The continued tonic or clonic spasm results in marked hypertrophy of the muscles involved. Accompanying hypertrophy is a fibrotic change, which results in permanent contractures in many cases. These are not relieved by nerve section, but require, in addition, tenotomy and myotomy of some muscles.

The progress of the disease is not constant. In some cases the disease may gradually involve adjacent muscles and remain unilateral, while in others it may progress to muscles of the other side. Occasionally the muscles on both sides are affected equally at the same time. If the patient has had encephalitis, it is possible that the torticollis may be the initial postencephalitic symptom; therefore, caution should be employed in advocating any radical treatment, since other muscles, especially those of the trunk, may become affected subsequently and the patient may be further incapacitated. In all cases, the symptoms subside when the patient is asleep. Often the patient controls the clonic spasms by supporting the chin with the hand or by resting the head on the back of a chair. The symptoms invariably are exaggerated when the patient meets strangers, is being observed by physicians, or is subjected to emotional strain.

DIFFERENTIAL DIAGNOSIS

The most difficult problem in the study of patients suffering from spasmodic torticollis is to determine whether or not the manifestations are of psychogenic or organic origin. It is extremely important to make this distinction, because surgical procedures are not justified in the psychogenic type of case. At the Mayo Clinic, these patients are studied carefully from general physical, neurological, and psychiatric points of view before treatment is recommended.

A review of a patient's medical history is extremely essential for, if remissions in the course of the disease have occurred, the condition is probably of psychogenic origin. The medical history will reveal the relationship of the onset of symptoms to the patient's emotional reactions to his environment.

After the psychogenic factors have been investigated, it is necessary to determine the presence of any previous cerebral or meningeal diseases or injuries to the brain, nerves, or muscles. If any such diseases have occurred, they would point toward an organic basis for the development of the patient's symptoms. Even though there is an organic basis, the symptoms are usually exaggerated by the emotional reaction of the patient. In the organic type, the spasm is more likely to be tonic than clonic, and furthermore, hypertrophy of the affected muscle is greater than it is in the functional type. In the psychogenic or functional type, the patient is inclined to toss his head from side to side, the movements are jerky, and the muscles are more easily relaxed than when the lesion is of the organic type. When the symptoms are of organic origin, contraction of the muscles will begin in a slow movement, spread until the height of a contraction is reached, and continue for a much longer period than it does when the condition is of functional origin.

Nerve block with procaine hydrochloride has been used in an attempt to differentiate further between the psychogenic and organic types. In the organic type, spasm in the muscle disappears when the nerves are completely anaesthetized, while in the functional type, in spite of thorough anaesthetization of the nerves, the patient will continue to toss or jerk the head in a series of abnormal movements. Though this response to the test is not absolutely pathognomonic of an organic lesion, the test is of value in differentiating between organic and functional types.

Unilateral block of the spinal accessory nerve and the upper three cervical nerves with procaine hydrochloride is of additional value in determining the presence or absence of spasm, or the degree of spasm on the side opposite to the muscles chiefly involved. Thorough relaxation of the affected muscles permits the opposite group to perform without interference. This test is significant, because unilateral section of the spinal accessory nerve would not be advisable if the muscles on the opposite side are affected also.

TREATMENT

Conservative Measures

The treatment of spasmodic torticollis is based upon the severity and duration of symptoms and the type of torticollis present. Since types may overlap, a conservative course of treatment should be employed first in all cases. By conservative treatment is meant the use of a medical regimen before any surgical procedure is advocated or performed. The medical regimen usually consists of prolonged rest, change of vocation, and the use of physical therapy; the administration of drugs, such as belladonna (rabellon), scopolamine, phenobarbital, vitamin B (especially nicotinic acid), and occasionally quinine; and the use of a plaster cast to immobilize the head and neck.

The authors' experience with the conservative treatment of spasmodic torticollis has not been encouraging, particularly in cases of the organic type. This experience covers use of traction to the head when the patient is recumbent in bed, various types of braces to support the head, and plaster casts; as well as physical therapy, including massage, diathermy, electrotherapy, and exercises. Many of the patients were more comfortable and often the spasmodic contractions ceased when they were in bed, especially if traction had been applied to the head. In no instance, however, was improvement of a permanent nature derived from such treatment.

Some years ago, after encouraging reports had appeared on the results of prolonged fixation in plaster-of-Paris casts, this method of treatment was tried in several cases. In most instances, the casts were applied carefully with the patients under general anaesthesia to ensure maximum relaxation. The casts covered the head and shoulders and, in some cases, extended down to the level of the lowest rib; in other cases they extended to the pelvis. Most of the patients could not or would not tolerate the casts for more than a few days, and it became necessary to remove them. In one or two cases the casts were

tolerated for a long period. In one case in which a cast was tolerated for several months, some benefit was thought to have followed its use, but it is doubtful whether the cast had any more to do with the improvement than the enforced prolonged rest. The case was one of extensive muscular dystonia with maximal spasm in the neck, and was not one of a strictly localized spasmodic torticollis. Our efforts with plaster-of-Paris casts, therefore, were discouraging. The same may be said of various types of braces to support the head. It is almost impossible to make a brace that holds the head steady, and the constant tugging and irritation are more than the patient can tolerate, except in the mildest cases.

In some instances of functional origin, these conservative measures have been found helpful and usually can be tolerated. The diagnosis of a functional type of spasmodic torticollis, therefore, justifies the use of such measures for a long period.

Surgical Treatment

When conservative measures fail in the treatment of the organic type, and when the symptoms are severe enough to produce pain and interfere with normal activity, operation must be considered, especially if an organic basis for the symptoms has been found.

Various operative procedures have been employed. The indications for each depend on the degree of spasm and contracture present and the extent of involvement. The operative procedures used, which will be mentioned in more detail, are as follows: unilateral section of the spinal accessory nerve in the neck; bilateral section of the spinal accessory nerves; section of one or more spinal accessory nerves, combined with section of the upper three cervical nerves as they leave the intervertebral foramina; section of the spinal accessory nerves and cervical nerves, with tenotomy and myotomy of the contracted muscles; combined operation, which includes an intracranial bilateral section of the spinal accessory nerves and rhizotomy of the upper three cervical nerves through a laminectomy wound; and a bone graft placed in the occipitocervical field after section of the spinal accessory nerves and rhizotomy of the upper three cervical nerves, when evidence of a subluxation of the upper cervical portion of the spinal column is found following extensive section of nerves.

Single or bilateral sections of the spinal accessory nerves are employed only when the sternocleidomastoid and the trapezius appear to be the muscles chiefly affected. The additional section of the cervical nerves is resorted to when the splenius capitis, the splenius cervicis, and the levator scapulae muscles also appear to be included in the unilateral spasm complex. The results of these procedures are not too gratifying, but they reduce the spasm to such an extent that the patient is able to carry on with his work.

In this series, section of the spinal accessory nerve was performed in twenty-one cases. In two, bilateral section was performed. One patient was completely relieved, sixteen were improved, and four obtained no relief. In four additional cases, cervical unilateral section of the spinal accessory nerve and the upper three cervical nerves was performed, and little or no relief was obtained.

If satisfactory relief is to be obtained when several muscles on both sides of the neck are affected, a major procedure is necessary. This procedure consists of bilateral section of the spinal accessory nerves and bilateral rhizotomy of the motor roots of the upper three cervical nerves. In some cases in which this procedure has been employed, the spinal accessory nerves have been divided in the cervical region prior to laminectomy and rhizotomy. The nerves were identified on the mesial side of the sternocleidomastoid muscle before they entered the muscle. The rhizotomy was performed through a laminectomy incision, which consisted of bilateral removal of the lamina of the first and second cervical vertebrae. No difficulty ever is encountered in identifying the second and third cervical roots, but occasionally the first cervical motor root may be overlooked, since it is intimately associated with, and lies anterior to, the vertebral artery as it enters the cranial cavity.

Intraspinal section of the spinal accessory nerves has not always been satisfactory, because section of these nerves at the level of the first cervical nerve root has not included all of the motor fibers passing into the nerve. For this reason, intracranial section of the

Fig. 1-A

Subluxation with anterior curvature of upper cervical vertebrae.

Fig. 1-B

Correction of subluxation by wearing a celluloid collar.

spinal accessory nerves just as they enter the jugular foramina has been performed. This extensive procedure of bilateral intracranial section of the spinal accessory nerves, and bilateral rhizotomy of the upper cervical roots, has given some satisfactory results. The muscle spasms have been completely relieved, without too much interference with the movements of the head and without too much deformity from atrophy. In certain cases, however, subluxation with anterior curvature of the upper cervical vertebrae has resulted; the patient's head has fallen forward; and the mandible has pressed into the neck in such a manner as to interfere with breathing, swallowing, and speaking (Fig. 1-A). This deformity may be corrected partially by the wearing of a Thomas collar or an especially adapted celluloid collar (Fig. 1-B). Patients object to wearing this collar for the rest of their lives, however. The subluxation is most likely to occur in cases in which the patient

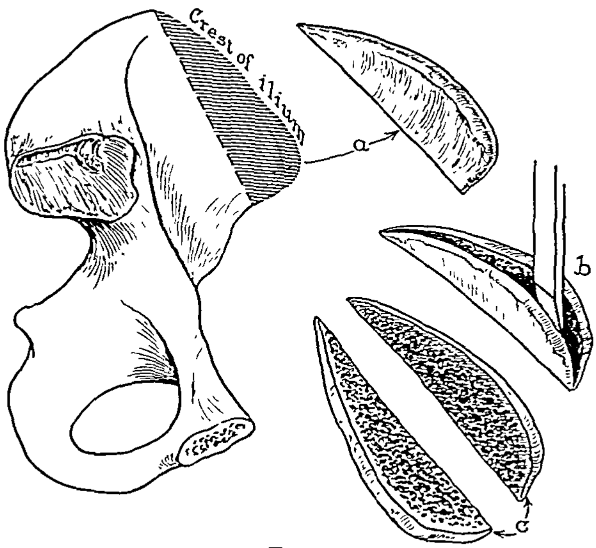

Fig. 2

a: Removal of the bone graft from the crest of the ilium.

b and *c*: Further preparation of the bone graft by dividing it into two parts.

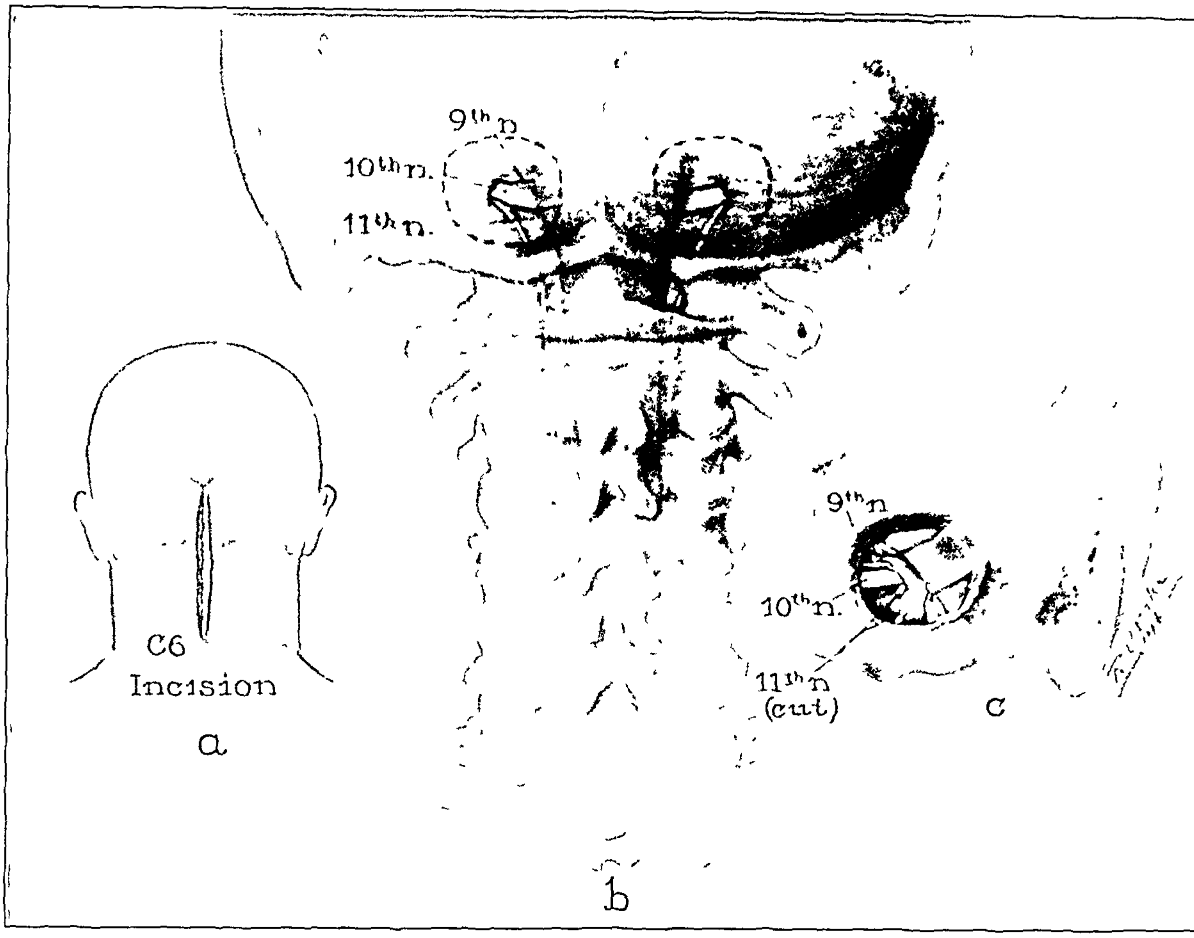

FIG. 3

a: The incision employed to expose the occipital bone and upper cervical portion of the spinal column.

b: The positions of the two trephine craniotomies employed in sectioning the spinal accessory nerves.

c: The site of the intracranial section of the spinal accessory nerve.

has a rather large and heavy head, because the weight of the head causes it to tilt forward on the cervical portion of the spinal column. Subluxation also occurs in patients who are compelled to perform heavy manual labor and in persons who frequently shift the position of their bodies in performing their duties.

The complaint of forward displacement of the head with difficulty in breathing, swallowing, and speaking, plus the nuisance of wearing a collar, prompted the authors to devise an operative procedure which included bilateral intracranial section of the spinal accessory nerves (Fig. 3) and bilateral rhizotomy of the upper three cervical nerves (Fig. 4), with the introduction of a bone graft which had been taken from the ilium and placed in the occipitocervical space. The graft was shaped so that it could be transfixed to the postero-inferior surface of the occipital bone, placed laterally over the ends of the first and second cervical laminae, and lateral to the spines of the cervical vertebrae over the third, fourth, and fifth cervical laminae.

Bone from the iliac crest is most suitable for the bone graft. Bone from the anterior portion of the iliac crest is preferred, as a longer piece of bone can be obtained than from the posterior portion. The first step of the bone-grafting part of the operation is carried out with the patient in the supine position. An incision is made along the anterior third of the iliac crest to a point one inch (2.5 centimeters) below the anterior superior spine. The muscle is carefully dissected from the iliac crest and the anterior superior spine for a distance of about three inches (7.6 centimeters). The ilium is stripped free of all attachments downward for about one inch from the crest, and this portion of the ilium is removed with

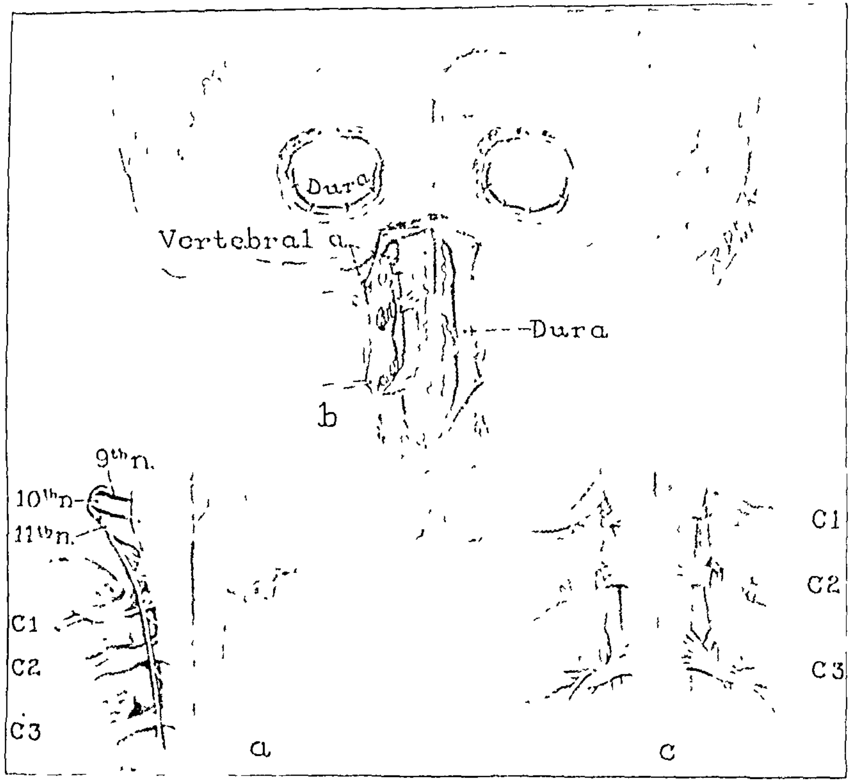

FIG. 4

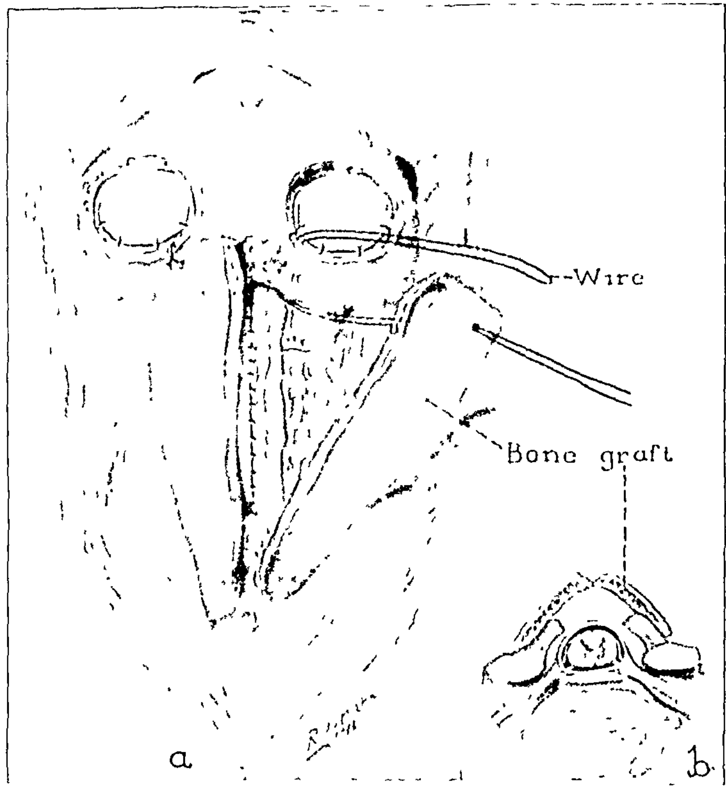

FIG. 5

Fig. 4: *a*: The anatomical relationship of the upper three cervical nerves to the vertebral artery and the spinal accessory nerve. *b* and *c*: The bilateral rhizotomy of the first and second cervical nerves and the motor root of the third cervical nerve.

Fig. 5: *a*: The procedure employed in preparing the field; shaping the graft, with its introduction and fixation; and securing it in position by wiring the upper end of the graft to the occipital bone with heavy non-corrosive wire. *b*: The relationship of the bone grafts to remaining portions of the lamina and to each other.

a sharp osteotome. The graft then is split longitudinally, as shown in Figure 2. As a rule, the graft is found to fit fairly well into the bed prepared for it and the contour of the anterior superior spine fits well into the occipito-atloid angle. Before placement of the graft, holes are drilled in both upper ends in order to pass the wire through the graft, as well as through the holes previously made in the skull lateral to the mid-line. Half of the graft is placed on each side of the vertebra to act as a roof over the spinal canal. The wires are passed through the two pieces of the graft and the holes in the occiput, and are twisted until they hold the graft snugly against the occiput and atlas. The grafts may be trimmed along their border to ensure accurate fitting against the other cervical vertebrae (Fig. 5).

Where a sufficient amount of lamina is left, the edge of the graft can be placed firmly against it and, when the upper end of the graft is fixed, the danger of slipping is minimized (Fig. 6). The lower end of the graft is held in place by suturing the muscles firmly over it.

After closure of the wound, a plaster cast is applied. This must cover the head, neck, shoulders, and most of the thorax. It should be applied carefully and should be padded carefully, but not too heavily. Openings should be made for the ears, as well as for the face. Various other types of fixation have been used; these usually have been plaster shells, made before operation, and metal and leather splints. Their use has the advantage of shortening the time on the operating table, but neither can be made to fit as accurately or as satisfactorily as the cast which is applied carefully at the end of the operation.

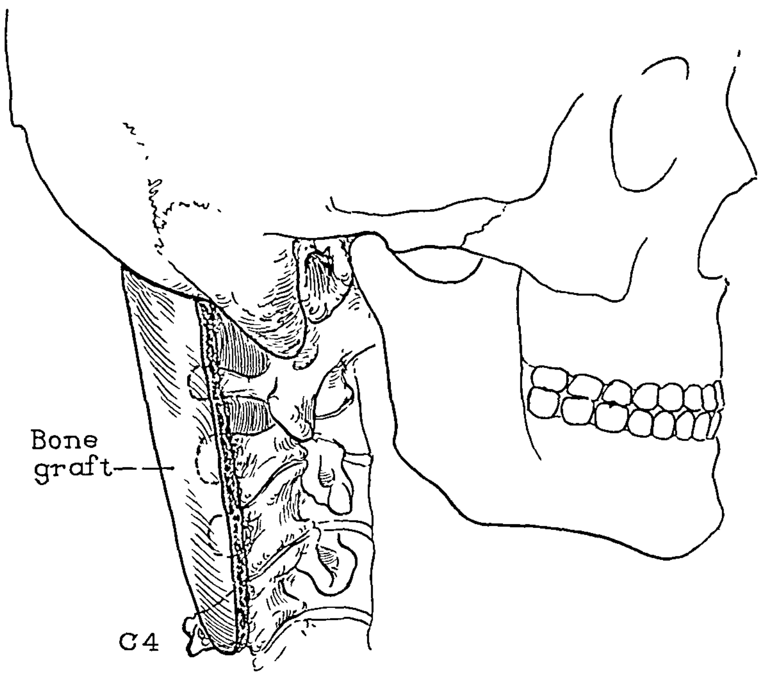

FIG. 6

Diagram illustrating the position of the bone graft. The length of the graft and the close contact made with the occipital bone should be noted.

Two weeks after operation, a window is cut in the cast and the sutures are removed through it. Care must be taken to see that the cast is not weakened at this stage. If it is weakened, it should be reinforced to prevent breaking. The cast should be worn for from ten to twelve weeks. After its removal a metal and leather collar is made, and this is worn for an additional three months. If, at the end of three months, roentgenograms show solid union of the grafts in the occipitocervical region, the support may be discontinued. If sufficient union has not taken place, the support should be continued until union is complete.

The following observations were made by the authors while they were developing this extensive combined operation of intracranial nerve section, rhizotomy, and fusion: In one patient the combined operation was performed successfully and the relief of muscle spasm in the neck was satisfactory, but dystonia developed, chiefly in the muscles of the back and trunk. The patient was incapacitated and the operation was made of little or no value.

In another patient, bilateral section of the spinal accessory nerves and unilateral section of the upper three cervical nerves were first performed through an incision posterior to the sternocleidomastoid muscle. The immediate temporary result appeared to be satisfactory, but the patient returned with an extension of symptoms which necessitated the combined operation. The results seemed satisfactory, but before the plaster cast was

FIG. 7

FIG. 8

FIG 7: Results accomplished in permanently correcting the subluxation by use of a bone graft. (Same patient as shown in Figs. 1-A and 1-B.)

FIG 8 Subluxation of the cervical vertebrae has been prevented by the combined operation, which included section of spinal nerves, rhizotomy of cervical nerves, and fusion. Roentgenogram taken three years after operation.

applied to the head, neck, and trunk, symptoms of pressure on the medulla suddenly developed and the patient died. Her death undoubtedly was due to slipping of the bone graft. This prompted a change in the technique so that at present, longer, double bone grafts are used, which are more thoroughly fixed to the occipital bone by heavier silver wire.

In another case, the authors ligated a rather large intervertebral artery which followed the second cervical nerve, believing the adequate blood supply to that portion of the cord came from the dorsal and anterior spinal arteries. Unilateral pyramidal signs developed after the operation and subsequently the patient died. This patient did not have a bone graft, but did have the extensive operation of section of the spinal accessory nerves and rhizotomy of the cervical nerves.

In still another case, respiratory difficulty was encountered when the fourth cervical motor roots on both sides were included in order to denervate the splenius muscle thoroughly. Pneumonia developed, and the patient succumbed.

Another patient was relieved of spasm following the major nerve operations, but was compelled to wear a brace until a graft was introduced, which resulted in adequate fusion, corrected the deformity, and eliminated the necessity of wearing a collar (Fig. 7).

One patient required additional surgery. The first operation was performed on November 27, 1942, at which time bilateral rhizotomy of the upper three cervical nerves, with an intraspinal section of the spinal accessory nerves at the level of the first cervical nerves, was combined with a fusion operation. Unfortunately, certain spasms and contractures still remained, so it became necessary to section the cervical nerves in the neck on the mesial side of the sternocleidomastoid muscles, and to perform myomectomy of the sternocleidomastoid muscle on the right side to relieve the contractures in this muscle. This man has been observed from time to time and the ultimate result is extremely satisfactory (Fig. 8). The time interval from the original operation to the last interview was three years.

COMMENT

In view of late results in the two cases just mentioned, the authors believe that the combined operation—bilateral intracranial section of the spinal accessory nerves and bilateral rhizotomy of the upper three cervical nerves, particularly the anterior roots, with the introduction of a bone graft at the same operation—is indicated for patients with marked muscle spasm on both sides, who are compelled to do manual labor, and for those who have large heads. The major operation on the nerves can be employed without a bone graft for patients whose occupations do not require manual labor. If difficulty in the forward tilting of the head should occur, with impairment in breathing, swallowing, or speaking, a subsequent operation for fusion could be performed. This combined operation of section of nerves and fusion of bone is a major procedure, and should only be employed when the patient is incapacitated as the result of spasmodic torticollis.

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INTRAMEDULLARY PINNING OF DIAPHYSEAL FRACTURES

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HISTORICAL BACKGROUND

Lambotte has practised the axial method of osteosynthesis of the clavicle since 1907. In 1910, at the *Société Belge de Chirurgie*, he presented a communication on the use of longitudinal screws in fractures with displacement. Later he substituted a carpenter's nail for the screw, because the head of the screw made a projection under the skin; and he is actually using a non-oxidizable nail with a groove. About the same time he accomplished the longitudinal fixation of subtrochanteric fractures by means of a screw, thirteen centimeters long. Much later he applied osteosynthesis by a transarticular approach, and also subcutaneously in transverse fractures of the phalanges (1924), in fractures of the metacarpals, of the upper end of the humerus, and of the lower end of the radius and ulna.

Since 1935, Joly has advocated axial transfixion, sometimes by open and sometimes by closed methods, in a large number of fractures,—of the clavicle, metacarpals, phalanges, toes, carpal scaphoid, malleoli, and rarely of the head of the humerus. He used a Kirschner wire as the material implanted. Danis extolled the use of Kirschner wire to maintain the long axis of the bones of the forearm and of the lower third of the fibula in malleolar fractures.

This great Belgian contribution of an original method of osteosynthesis did not seem to arouse in foreign countries the interest which it merited. Without examining the reasons for this lack of interest, we give several examples.

In America, in 1937 and in 1939, L. V. Rush and H. L. Rush presented as entirely new a technique of longitudinal fixation of the fragments of the superior extremity of the ulna or of the femur, by means of a Steinmann pin. In their method the pin projected from the skin; this prosthesis was temporary,—that is, after a few weeks it was extracted.

In England, Lambrinudi in 1940 presented as a discovery the intramedullary use of Kirschner wires. "The use of intramedullary wires in the treatment of fractures has, so far as I know, not previously been described", he wrote. He referred to three cases in which it was used,—two of the forearm and one of the femur. He also lets the wire protrude through the skin, and removes it between the fourth and fifth weeks. His idea, if we may judge from the comment of disapproval by Watson-Jones in his treatise of 1943, did not seem to have a very successful reception.

The various procedures of osteosynthesis to which we have referred secured longitudinal fixation by a screw, a nail, a wire, or a pin, which traversed the two fragments for a certain distance, following the long axis of the limb, and, when necessary, crossed one or even two adjoining articulations. The fixation material might be in the cortex or might lie obliquely.

The essential characteristic of none of these interventions is intramedullary, properly speaking.

Following the work of Albee, of Cornioley, of Neuman, and of others, osteosynthesis of the long bones by means of bone grafts, living or dead, was advocated. At times small bits of resorbable material were introduced into the medullary cavity at the site of fracture, and they played the role of a bolt or of a pin between the fragments. These procedures had nothing in common with the implantation of metal fixation which we are now describing.

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It was Küntscher who showed convincingly that osteosynthesis could be secured along the medullary cavity of the long bones. His first paper was presented in March 1940 to the *Deutsche Kongress für Chirurgie*. He described longitudinal fixation by means of metallic material, occupying the full length of the medullary space. The material was strong,—a rod of as large size as the bone canal permitted. The material was introduced by an extra-articular route, as far from the fracture site as possible, and without exposure of the fracture. The material was completely buried. The end of the prosthesis which extended beyond the bone was covered by the soft parts and the skin. The reduction had been attained by external manoeuvres before the intramedullary fixation. After consolidation of the bone, the prosthesis was extracted. Thanks to the adaptability of the material and to the technical skill which Küntscher displayed at the outset, one of the most difficult problems of osteosynthesis was solved,—the diaphyseal fracture of the femur. All previous operators by the longitudinal route had only dared to operate upon the superficial bone, the short bones, or fractures at the extremities of bones.

The first communication on this method was not well received; it was called an "antiphysiological method"! In spite of the theoretical criticisms brought against it, the method had a growing vogue in the Central European countries. The early results of many surgeons appeared to be conclusive; the statistics were ample, the published reports were numerous, as shown by the references in our bibliography.

In France, attention was attracted to this method by its use in the victims of enforced labor, men wounded in Germany, where they were operated upon. When these men returned to France, they asked their surgeons to remove the prostheses. (See the communication of Mondor and Nardi on this subject, presented to the *Académie de Chirurgie* in 1942.) Later appeared the fruitful essays of Christian Rocher, of Jeanneney and Magendie of Bordeaux, those of Leveuf, and of Michel-Brechet and Godart of Paris (1944).

In the Scandinavian countries, knowledge of the procedure was widely spread by Westerborn in 1944.

In Belgium, we ourselves have been working on this problem for two years; our first operation was performed June 1, 1943 (Fig. 5-B). Our actual experience with this method was secured from a total of fifty-five operations.

OBJECTIONS TO THE METHOD

The chief objection to medullary pinning is the destruction of the bone marrow. The lesions produced blindly might lead to unpleasant sequelae. This apprehension was voiced at the first exposition of the technique in 1940; various surgeons asked this question in our hearing. Even if the prosthesis should destroy all of the medullary contents, which is scarcely probable, we know very well that the individual is easily able to do without the hematopoietic element in one of the long bones. Patients who have had amputations which entailed the loss of the larger segments of a limb never show evidence of the loss of bone marrow in the histological examination of the blood. Also in curettage for osteomyelitis and in bone-grafting, there is at times serious destruction of the bone marrow.

Slany, in 1944, studied the blood of patients subjected to medullary pinning. After this intervention he noted an increase in the number of reticulocytes, the presence of young leukocytic forms, eosinophils in infants and adolescents, and finally in certain individuals an anaemia,—a diminution in the number of red cells and in the hemoglobin. After the removal of the prosthesis, the return to the normal blood picture was rapid. Since fractures of the long bones, regardless of the method of treatment used, have a tendency to provoke manifestations in the blood similar to those which appear with this treatment, and since the symptoms are mild, the problem may be of interest to the hematologist, but is of little concern to the surgeon. It is better to remove the material, when it is possible to do so.

The risk of fat embolism is a more important consideration. Concerning this matter, it is the practice, not the theory, which gives the answer. Statistics of more than a hundred

fixations, which have been published, affirm that the method does not expose to the danger of embolism. We have watched our patients who have been operated upon most particularly in this matter; and we can verify this statement. In more than fifty osteosyntheses by the intramedullary method, only once have we seen postoperative pulmonary embolism.

This was in a patient of thirty-four years, who presented a spiral fracture of the middle third of the femur. Three days after the accident, the bone was pinned after closed reduction. Operation was easy and there was no shock. Forty-eight hours later pain, increased by deep breathing, was found at a point under the ribs on the left side. The heart beat was regular, the pulse twenty-two beats to the quarter. Râles were heard at the left base. The following day the temperature was 39 degrees centigrade, and there was slight hemoptysis. On subsequent days there was gradual subsidence of the fever. On the seventh day there was no fever, and his condition had returned to normal. This patient was operated upon more than a month ago and is included in the group here presented.

It is apparent that only experience on a vast scale will be able to answer definitely the question concerning the danger of embolism. At present, the risk appears to be slight.

The possibilities of operative infection are present, as in all surgical procedures, particularly in operations upon the bones. In our opinion, the septic complications—all other factors being equal—are less to be feared after medullary pinning than following other methods of osteosynthesis. There is little trauma, and the method entails less disturbance of the muscles and manipulation of the fragments than occurs with open procedures. The few suppurations which we have seen followed osteosynthesis in compound fractures, a type of fracture in which the method is contra-indicated. In any case, we have learned that the presence of a foreign body in the medullary cavity does not in itself constitute a predisposition to infection. Osteomyelitis in the entire diaphysis need not be feared, even when the operative site becomes infected.

MERITS OF THE METHOD

1. The operation causes little shock. Medullary osteosynthesis is a safe intervention. The incision is short; there is little hemorrhage; bleeding is reduced to a minimum, since the site of the fracture is not often opened. The postoperative well-being and the objective state of the patient are truly astounding, and they remain so in the days that follow.

2. The prosthesis is simple. The bloodless reduction of the fracture without doubt requires dexterity on the part of the surgeon, and is tedious, because of roentgenographic control and successive corrections. It is a stage of the operation which is unimportant to the patient, since the operation is performed under spinal or local anaesthesia. When end-to-end apposition has been obtained, the insertion of the prosthesis is easy, for it does not require particular manual dexterity. With the pin in place, the operation is practically finished. If it is necessary to perform an open reduction, operative reduction of the fracture is all that is required, usually easy in fresh fractures. The problem of osteosynthesis is thus simplified. In other methods of osteosynthesis, the difficulties arise in the fixation after reduction; this requires not only exposure of the site of the fracture for reduction, but also wide exposure. It is essential to maintain the coaptation of the fragments during the time the bed is prepared for the prosthesis, during the fitting, and while fixing it in place.

3. Formation of callus is rapid. Our observations verify those of others. The callus forms more quickly when medullary metallic fixation is employed than with any other method. After three weeks usually, periosteal calcification is readily seen in roentgenograms of a diaphyseal fracture of the femur. The exactness of the reduction, the possibility of axial impaction, the active mobilization of the limb,—all these do not in themselves explain the excitation of periosteal osteogenesis.

It may well be that the presence of a foreign body in the medullary canal is responsible for this. Küntscher introduced steel wires (V-2A) into the intact diaphyses of long

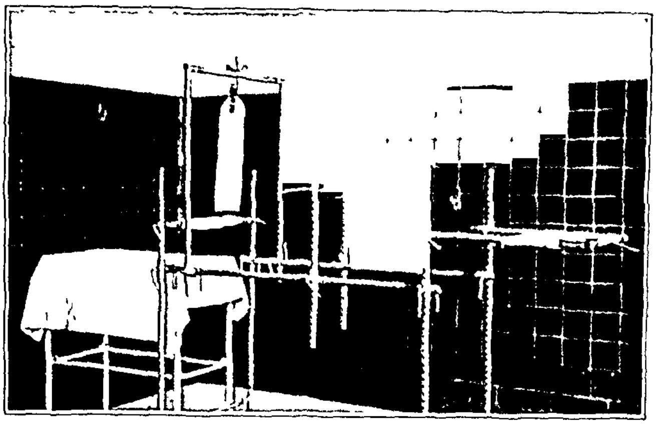

Fig. 1

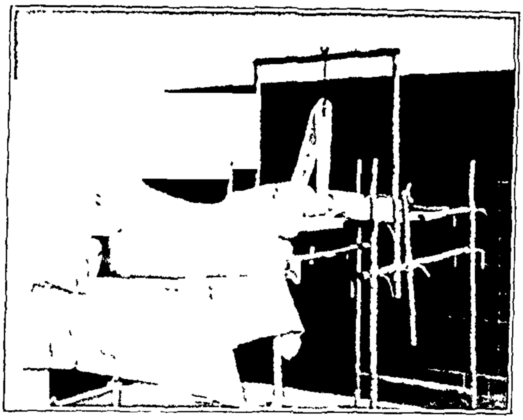

Fig. 2

Fig. 1: The author's apparatus, based on the same principle as the Böhler frame. It stands directly on the floor, not on a table. It is very large in order to permit better traction upward (by the sling) and anteriorly and posteriorly (by the traction screw).

Fig. 2: Apparatus at right angle to the operating table. Patient in position.

bones of dogs. A few weeks following this procedure, he observed thickening and calcification of the periosteum. The appearance was similar to the ossification seen in sarcoma. We do not know how to interpret these observations. Is that which takes place a defense reaction of bony tissue, comparable to that which takes place when there is a central sequestrum, or does the periosteum react to central pressure on the bone? Examination of our patients leads us to favor the second hypothesis. The hypertrophy of the callus is more intense whenever we use a thick prosthesis. It is less intense whenever the material is very thin (as Kirschner wire).

Whatever its cause may be, this tendency to exuberance of the bony cicatrix is a welcome result to the surgeon, since it takes place in fractures at the locations where he dreads pseudarthroses. Another consequence of this hypertrophy of callus is the necessity of removing the prosthesis after definite consolidation of the fracture.

4. Early mobilization is possible. Because there is no pain, because callus forms rapidly, and because the parts of the limb are firmly fixed, motion is resumed quickly. Active mobilization begins from the first days following operation. Patients with operations upon the thigh usually walk about with two canes by the sixth week. Those with operations upon the leg get about by the twelfth day. Patients with operations upon the upper arm are able to contract the deltoid muscle (Fig. 13-B); with operations upon the forearm, they can move the fingers. Massage and other forms of physiotherapy are generally superfluous, since the joints maintain their suppleness, the muscles their tonus, and the circulation its normal course. The period of hospitalization is greatly reduced, in comparison with that required by other methods of treatment, notably continuous extension.

THE FEMUR

If possible, femoral fractures are reduced under roentgenographic control by manipulation; if not, the fracture is exposed and the fragments are replaced under direct vision. The nail enters the medullary cavity by the supratrochanteric route. It traverses the entire length of the diaphysis; below, it is imbedded in the spongy tissue of the lower epiphysis. As a general rule, a plaster cast is unnecessary. The patient moves the limb during the first days after operation, and he is allowed to get up early.

Choice of Pin

During the German occupation of Belgium, it was impossible to procure the original material used, which consisted of pins having one section approximately in the form of a V. We were satisfied with U-shaped pins made from cylindrical bars of non-oxidizing steel

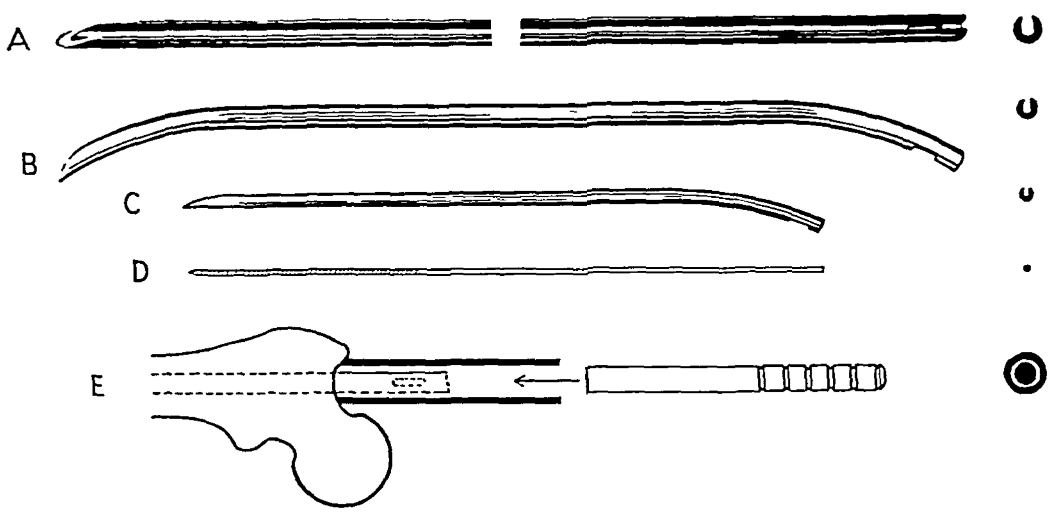

FIG 3

Prostheses and Pin Driver

A: Straight pin of grooved bar of steel (V-2A) One end is pointed, the other shows a small eye. In profile these pins are in the form of a U. For a femoral diaphysis, the diameter of the pin is usually eight millimeters The thickness of the sides of the U is two millimeters For the humerus and the ulna the pins are similar, but shorter and thinner

B: Tibial pin, made of the same material as the straight pin, and six to eight millimeters in diameter It is curved at both ends The point of the curve is generally 1.5 centimeters from the end.

C: Radial pin, five millimeters in diameter It has a single curve.

D: Threaded rod for the ulna and radius, two to three millimeters in diameter

E: Graduated pin driver The guiding tube has been slid over the pin up to the bone The mandril will be introduced into the tube The graduations on the mandril show the extent to which the pin penetrates the bone

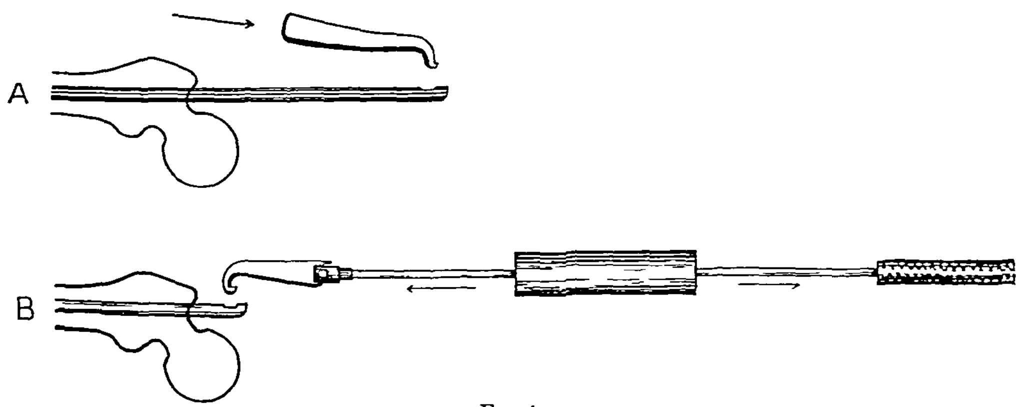

FIG. 4

Extractor

A The instrument is eighteen centimeters long A hook fits into the eyelet of the pin By blows with the tip of the hammer, one frees the prosthesis This instrument is useful in the operation when it is necessary to retract the pin in order to change its direction

B Hammer-extractor permits the freeing of a pin when the head of the pin alone is accessible (after consolidation) The rod, thirty-five centimeters long, has a hook attached to one end and a handle to the other A metallic mass, weighing one kilogram, moves freely on the rod While the assistant holds the handle, the surgeon drives the mass violently against the handle.

(V-2A). As to the thickness of the pin, it should be quite exact. If the pin is too thick, it may split the cortex; if too thin, there is a tendency for the fragments to play. It would seem important in each case to study the size of the medullary cavity from the roentgenograms; in practice, this thesis proves to be erroneous. The medullary cavity is not rectilinear; in the femur it is curved in two planes.

Our pin is straight. It acts efficiently, because it is wedged into an irregular canal, the walls of which it touches, sometimes one wall, sometimes the other. It traverses the entire length of the femur. The forces which are exerted are divided along a great distance of material. In this it differs from osteosynthesis with plates or bars, in which the prosthesis, very short, receives practically all the force of flexion or of torsion at one point. In practice, with adults we use pins less than nine millimeters in diameter.

The length of the pin should be determined before operation. Here again roentgenographic data seem superfluous, and may be the cause of error. The procedure is very simple; on the skin we measure the femur on the sound side, taking the distance from the top of the greater trochanter to the knee-joint line. From this measurement we subtract a constant figure, four centimeters; in this way we obtain a satisfactory approximation, whatever the size of the muscles may be. With roentgenographic control, we can judge how deeply the pin should be placed. The head of the pin may project level with the trochanter or, without inconvenience, it may project beyond it for three centimeters.

Position of the Patient

The ordinary orthopaedic table is not suitable. We use a Böhler frame for fractures of the lower extremity or a larger frame based on the same principles (Figs. 1 and 2). The patient is placed in lateral decubitus on the sound side. The trunk is flexed to a right angle with the thigh. In this position, access to the trochanteric region is easy.

Reduction

We operate under spinal anaesthesia. Traction is applied in the axis of the limb with a foot hitch. Overriding is reduced; and coaptation is secured by lateral straps. Verification of reduction is made by anteroposterior and lateral roentgenograms. (We have given up fluoroscopy, which presents a number of disadvantages. It is technically difficult to view the fracture through the screen and to operate at the same time. Fluoroscopy gives inexact information, and there is danger of radiodermatitis.) The reduction should be anatomical. The pin cannot be introduced if the medullary cavity has not regained its contour. Thus in fractures impossible to reduce, such as comminuted fractures and old fractures, it is necessary to expose the site of fracture. After an external, longitudinal incision, the fragments can be replaced easily. This does not require the wide exposure necessary in osteosynthesis by plates or screws.

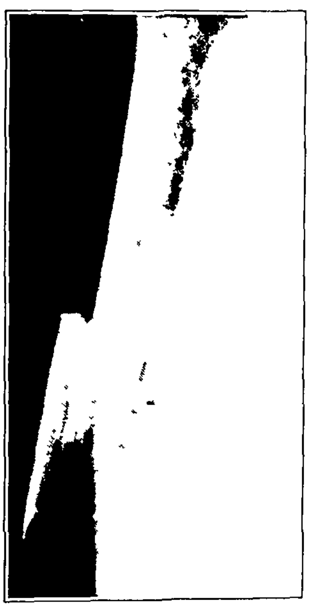

FIG. 5-A

Transverse fracture of the middle third of the femur. The patient, aged forty-nine, was injured in an accident on May 24, 1943. This was the first patient operated upon.

Introduction of the Pin

Through an incision of eight to ten centimeters in the supratrochanteric region (Fig. 2), the superior surface of the greater trochanter is reached, after retraction of the muscles. The point of introduction is not at the top of the trochanter, but at the junction of that prominence and the femoral neck, which is exactly at the prolongation of the medullary cavity. The cortex is trephined with a gouge. A guide is then introduced. This is a steel wire, three millimeters in diameter and forty centimeters long. Either by roentgenogram or, in an open reduction, by direct view, verification is made of the presence of the guide in the medullary cavity.

Osteosynthesis

The pin is slid along the guide and is driven into the medullary cavity by hammer blows. The guide is then removed. New roentgenograms show the position of the pin, its introduction into the distal fragment, and finally its

depth. It should reach the lower epiphysis, but should not perforate the knee joint. If, by accident, the prosthesis fails to enter the distal fragment, passing to the side, it must be extracted and replaced after any angulation has been corrected. The final suture of the wound presents no particular problem.

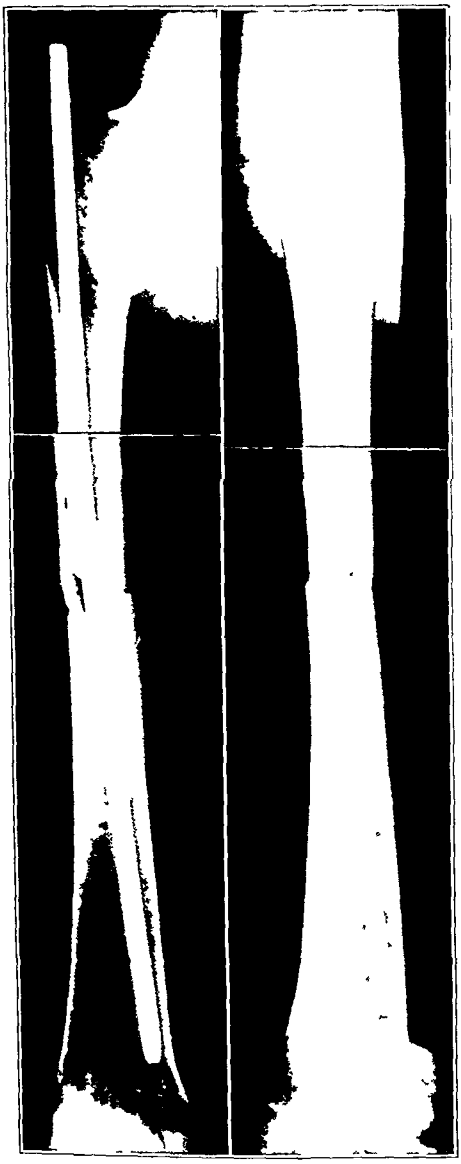

Fig 5-B

Fig 5-C

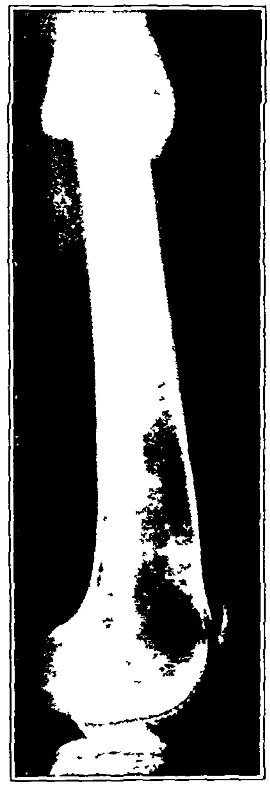

Fig 5-D

Fig 5-B: On June 1, 1943, osteosynthesis was performed under spinal anaesthesia Closed reduction was accomplished in the lateral position on the Bohler frame, with the aid of the fluoroscope. By supratrochanteric incision and after trephining at the junction of the trochanter and the femoral neck, a straight pin, thirty-eight centimeters long and nine millimeters thick, was inserted Walking was permitted by August 6

Figs. 5-C and 5-D Roentgenograms, taken January 21, 1944, showed solid union without shortening or angulation The pin had been removed on November 22, 1943 There was perfect function. The patient returned to work four months after operation

Postoperative Care

The limb is placed on a Braun frame. After the second day the patient may move his foot, and a little later the knee and the hip. After the joints have regained their normal range of motion, the patient is allowed up. Usually about the fifth or sixth week, he is able to walk with canes, and then without any support. Roentgenograms are taken to determine the degree of bony union.

Removal of the Prosthesis

Between the third and sixth months it is necessary to withdraw the prosthesis. For this a special extractor is necessary (Fig. 4). Pincers of the usual type and extractors of the Smith-Petersen type are of no avail. Not by strong traction alone can a well-fixed medullary pin be freed, for it was fixed in place by strong friction and by hammer blows. Only by a series of blows applied in the opposite direction in the axis of the bone is it possible to remove it. We use an instrument suggested by one that Stör described; it is very strong and it catches in the eye fashioned in the end of the prosthesis. To neglect the use of such an extractor is to court failure; upon this point we cannot insist too strongly.

Results

1. *Simple Fractures of the Upper and of the Middle Thirds of the Femur:* We encountered eight fractures in patients between the ages of seventeen and fifty-four years. Four of these were treated without the site of fracture being exposed; four were reduced by open operation. With the exception of those who presented other lesions, such as fracture of the pelvis, fracture of the leg, *et cetera,* all were walking easily between the first and second months. The pins were removed between the fourth and the seventh months. All of these fractures healed without shortening and without displacement, without muscle atrophy and without infection (Figs. 6-A, 6-B, and 6-C). We believe that these results are from all points of view much better than those obtained by continuous extension.

2. *Simple Fractures of the Lower Third:* The nearer to the knee is the site of the fracture, the less efficient is the fixation. It is necessary to anticipate the possibility of displacement of the distal fragment by rotation. To prevent this displacement after operation, we apply a large plaster cast, including the pelvis and foot. We have operated upon two fractures at the upper part of the lower third of the femur. In one case the result was satisfactory, although there was slight angulation because of the poor quality of the prosthesis; and in the other the result was difficult to evaluate. This was the case of a boy of sixteen; the fracture healed in the normal manner and the pin was removed in the fifth month. The boy walked normally and had returned to work. He fell again and fractured the femur at the same level. Following immobilization in plaster, the fracture healed with shortening of two centimeters. It is difficult to say whether the new fracture was caused by poor callus or by the second accident. (We have not treated by this method any fracture at the distal fourth of the femur.)

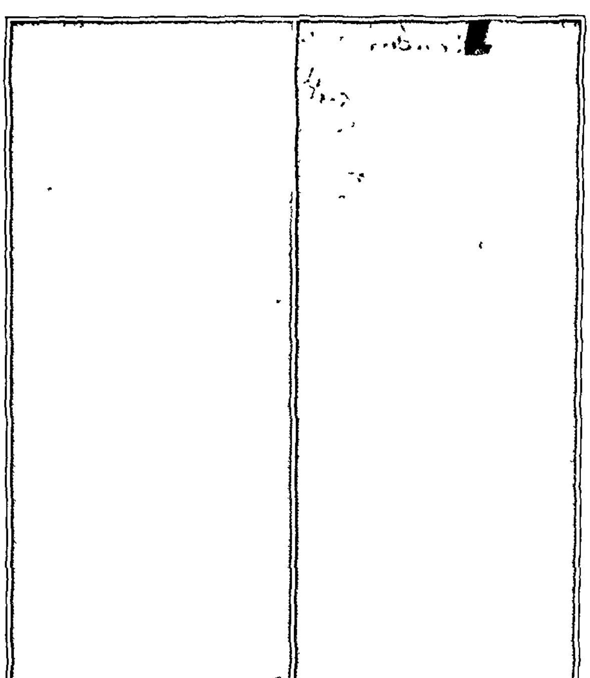

Fig. 6-A

Comminuted fracture of the middle third of the femur. The patient, aged seventeen years, had an accident on January 15, 1945. Osteosynthesis was performed on January 27, with spinal anaesthesia, traction, and open reduction. The fragments were held in position by a pin, forty centimeters long, inserted by a trochanteric route.

3. In *compound fractures* the results were poor. One fracture, resulting in three fragments and associated with an extensive wound of the soft parts, was operated upon a few hours after the accident; the patient died during the operation. In two compound fractures with minimum wounds, operation was delayed until the wounds appeared healed. Infection appeared in the two cases and was clearly connected with the original wounds.

Fig 6-B

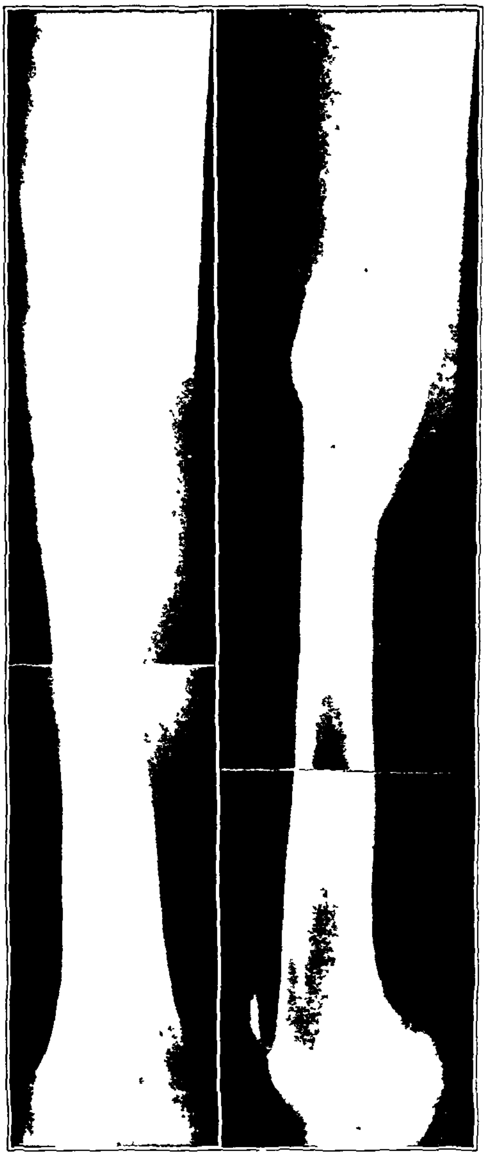

Fig 6-C

Fig 6-B Roentgenograms made April 6, 1945, showed good reduction with massive callus

Fig 6-C Follow-up roentgenograms, made July 3, 1945 The pin had been removed fifteen days before, five months after the reduction The functional result was perfect

4. *Pseudarthroses*: Two patients with old pseudarthroses had undergone varied treatments (extension, osteosynthesis, plaster fixation). Both were operated upon. Good consolidation occurred in one case (Figs. 8-A and 8-B); failure resulted in the other through an error in technique.

5. *Shortening*: An excellent result in equalization of the limbs was obtained in one case. This woman, twenty-seven years old, had a shortening from congenital dislocation of the hip. Five centimeters was removed from the normal femur and this was followed by intramedullary pinning and the application of a plaster cast. Union was complete and the result was perfect after four and one-half months.

6. *Pathological Fractures*: The criterion of "cure" is much more difficult to determine in such cases. A tabetic, fifty-two years old, presented a fracture of the upper third

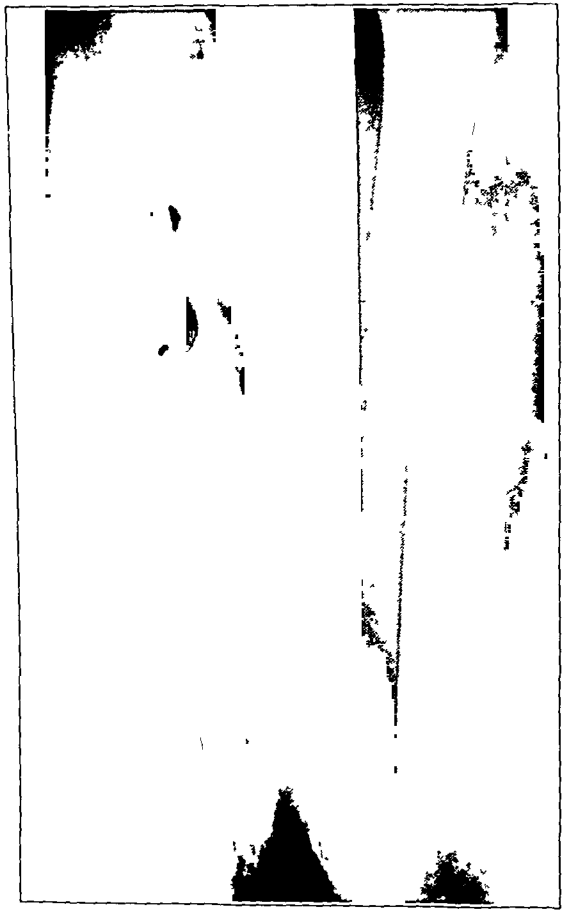

FIG. 7-A

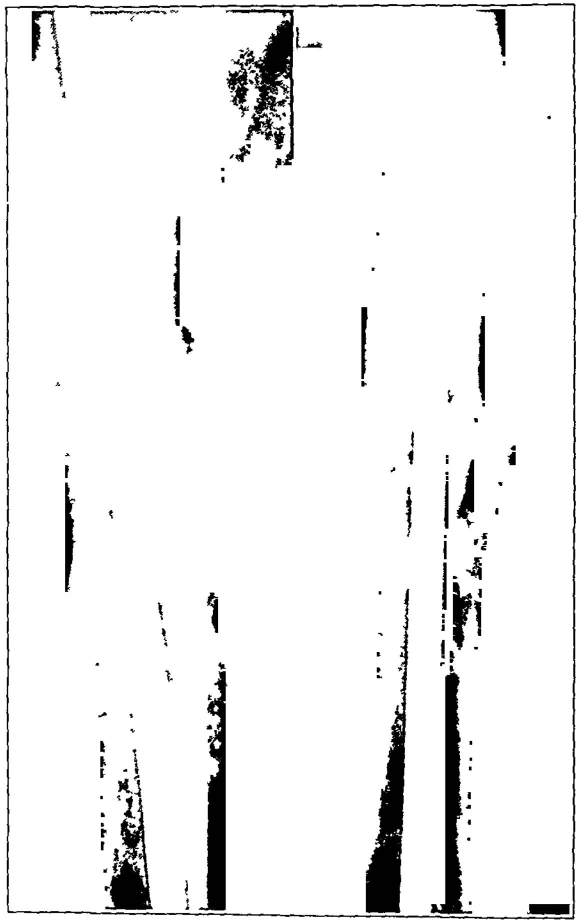

FIG. 7-B

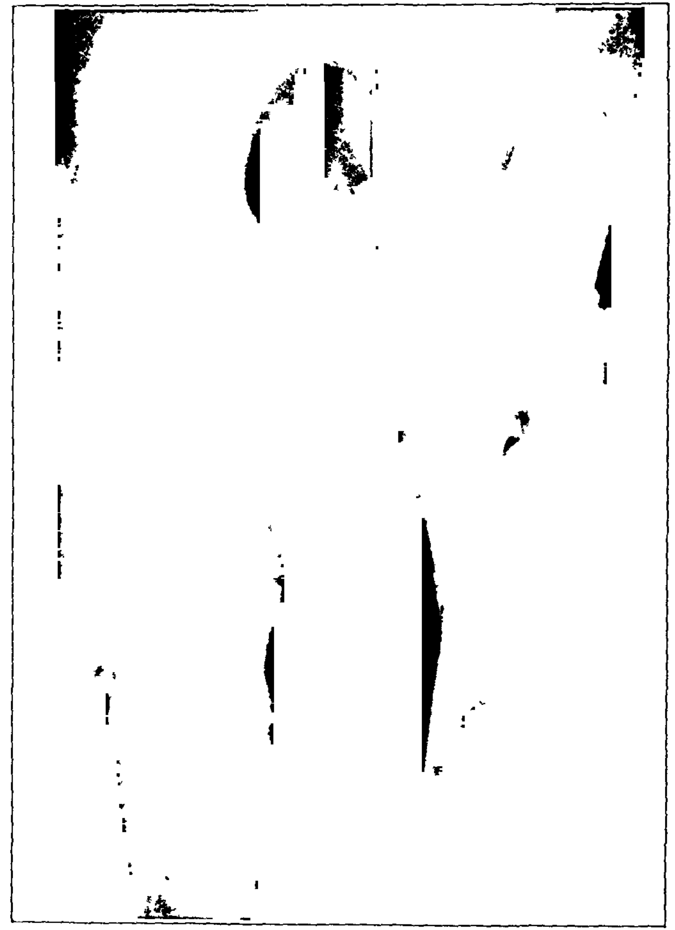

FIG. 7-C

Fig. 7-A: Comminuted fracture of the middle third of the left femur in a patient *twenty-three* years old. Osteosynthesis was performed September 16, 1944, under spinal anaesthesia. Traction was applied, with the patient on the Böhler frame; then open reduction and intramedullary pinning were done. A long plaster spica was applied for six weeks to prevent rotation.

Fig. 7-B: Roentgenograms made on October 30, 1944, forty-four days after operation. The patient was out of bed.

Fig. 7-C: Showing final result on May 15, 1945. A massive callus was palpable. The functional condition was perfect, without muscle atrophy or limitation of motion. The prosthesis had been removed four months after operation.

Fig. 8-A: Pseudarthrosis of the femur. Patient, sixty years old, was injured February 5, 1943; had already been subjected to osteosynthesis by bolts when admitted. Traction was continued, with plaster from pelvis to foot, without any change. The knee was ankylosed. Roentgenogram shows the pre-operative state. Eight months after the accident, on October 7, 1943, we did an intramedullary pinning.

Fig. 8-B: Roentgenograms on June 13, 1944, showed consolidated pseudarthrosis and markedly exuberant callus. The prosthesis used was very thin. Slight flexion occurred at the fracture site. Note also that calcification was produced about the end of the pin. In order to remove the prosthesis, it was necessary to break this bony covering with a blow of the hammer.

When last seen, on January 15, 1945, there was perfect consolidation. Patient walked without a cane, with heel raised three centimeters. Hip had 45 degrees of flexion, 30 degrees of abduction. Knee flexion was 50 degrees.

Fig. 8-A

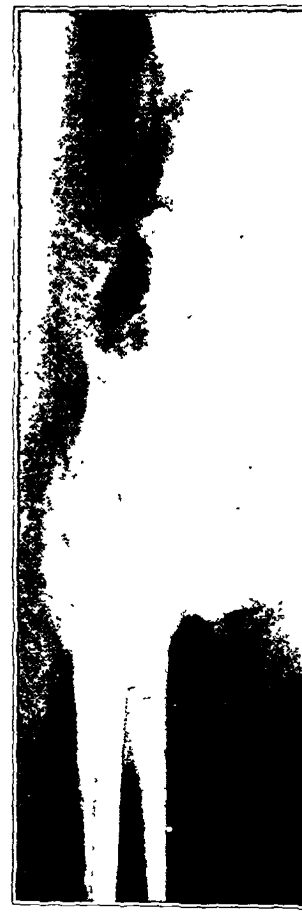

Fig. 8-B

of the femur, which healed perfectly. Two patients, sixty-two and seventy-three years old, respectively, with Paget's disease, with old pseudarthroses, and in very poor general condition, were treated by this method. One had good union; the other died on the twenty-third day. Two senile patients with spontaneous fractures, which occurred in bed, were operated upon. One, eighty years old, died on the fourth day. The other, seventy-three years old, had a normal postoperative course and died from apoplexy two months later. Two patients with inoperable tumors and spontaneous fractures were operated upon. One survived for one month. This patient was sixty-nine, with bone metastases of an epithelioma. The other, with multiple myeloma, survived for four months. It is evident that our attempts in these seven hopeless cases seemed to lessen their pain and, in five of the patients, made the nursing care easier.

Indications

From a total of twenty-three diaphyseal fractures of the femur, we are able to draw the following conclusions: Intramedullary osteosynthesis gives excellent results in closed fractures, particularly those in the upper third, in the middle third, and in the upper portion of the lower third. It is indicated in pseudarthrosis and in shortening of one femur for equalization of the limbs. It is of value in pathological fractures, where it is impossible to apply any other method. We advise against its use in compound fractures.

THE TIBIA

The principles comprise reduction of the fracture on the Böhler frame, the introduction of a bent pin through the anterior tuberosity of the tibia, and the application of an ambulatory plaster from the thigh to the toes.

Choice of Pin

The end of the pin is in the form of a V or a U. It is slightly curved. Its diameter is six to eight millimeters, depending upon the skeleton of the patient. For determination of

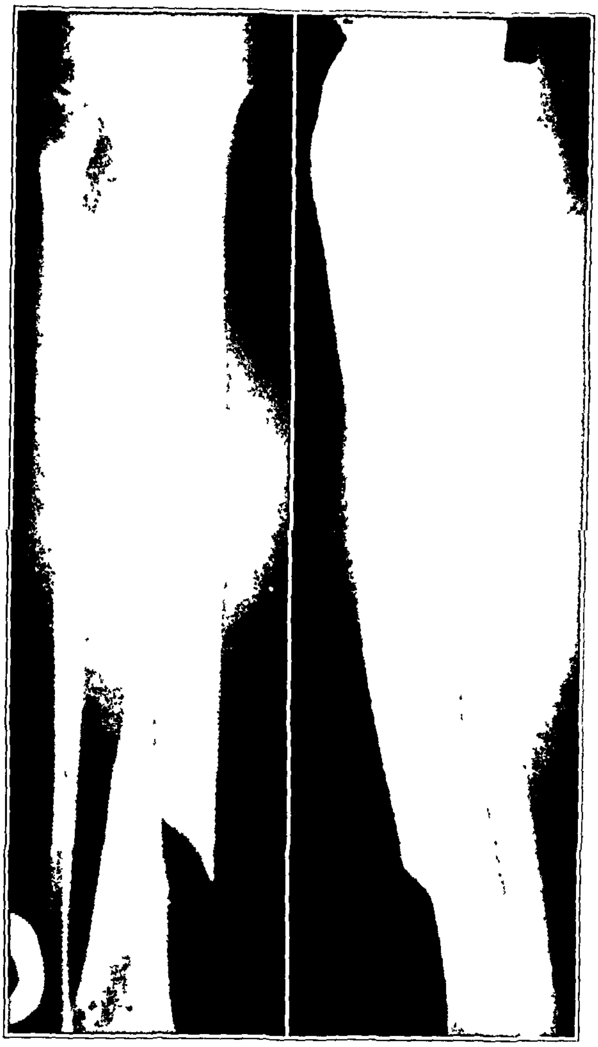

Fig. 9-A

Fig. 9-B

Fig. 9-A: Diaphyseal fractures of both bones of the leg. The patient, thirty years old, was injured January 1, 1944, by torsion. On January 7, closed reduction and pinning were done under spinal anaesthesia, with the patient on the Böhler frame.

Fig. 9-B: Showing result immediately after osteosynthesis. Patient was in ambulatory plaster for six weeks.

its length, the distance between the medial joint line of the knee and the tip of the medial malleolus is measured. From this length is subtracted four centimeters, or three centimeters if the fracture is situated very low.

Position of the Patient

The position used is that which Böhler described for the closed reduction of fractures of the leg. The knee is flexed markedly upon the special frame. The anterior tuberosity of the tibia is easily accessible. Traction on the foot does not require a Kirschner wire; a hitch suffices.

Reduction

Spinal anaesthesia gives ideal muscle relaxation. By palpation, fluoroscopy, or subsequent roentgenography, the reduction is verified. If it is not perfect the first time, which often occurs with spiral fractures, it may be necessary to expose the fracture site by a short incision, and reduce the fragments.

Introduction of the Pin

By a longitudinal incision, along the tibial crest, the anterior tuberosity is exposed. The point at which the cortex is trephined is immediately above this apophysis, at the

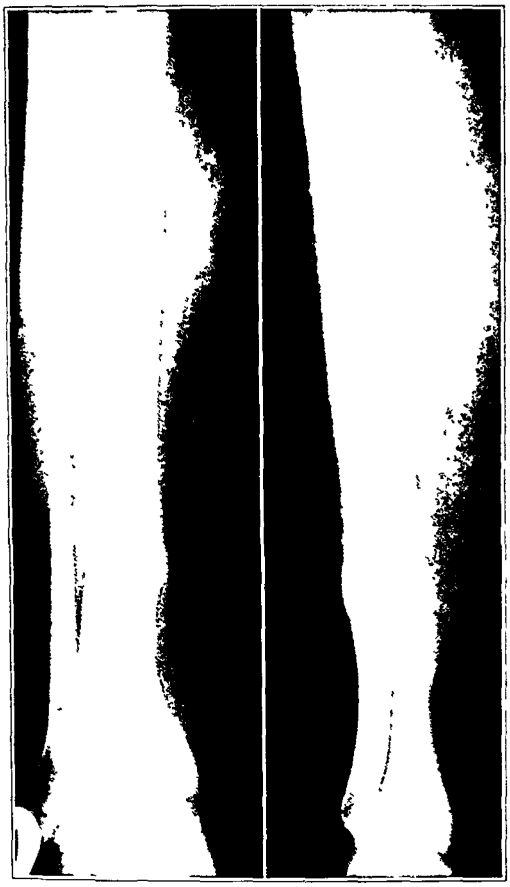

Fig. 9-C

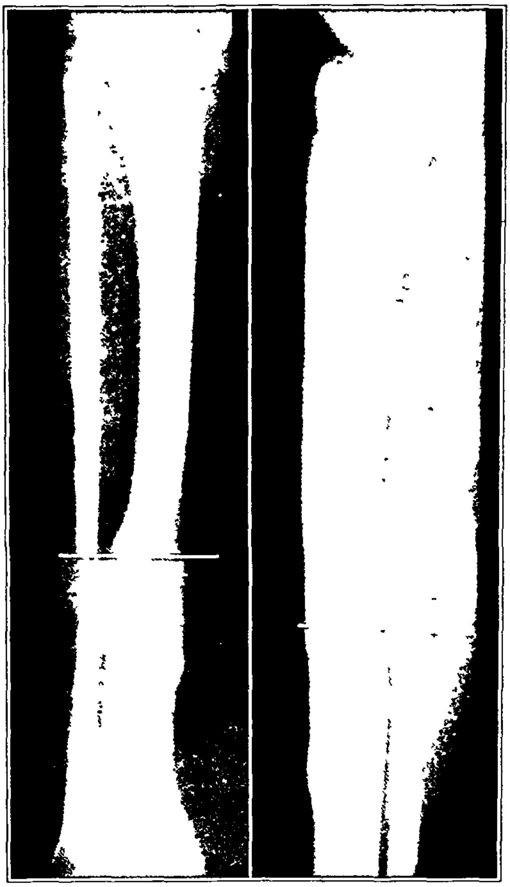

Fig. 9-D

Fig 9-C: Show result on September 29, 1944, with solid callus. The prosthesis was removed the next day.

Fig. 9-D: Result on May 25, 1945, sixteen months after operation.

insertion of the longest fibers of the patellar tendon. The concavity of the pin is turned forward. The pin is driven by a hammer into the medullary cavity of the proximal fragment.

Osteosynthesis

After the correct location of the pin has been verified by roentgenograms, the prosthesis is driven into the distal fragment, while an assistant maintains rigid reduction with a Lambotte clamp, if the site of fracture has been exposed. A final roentgenogram of the ankle determines the depth of penetration of the pin. The skin only is sutured, and a plaster is applied from mid-thigh to toes.

Postoperative Care

On the tenth day the plaster is removed. The stitches are taken out. A new plaster is applied, which is attached to a Telson patten. The patient is then permitted to get up and to leave the hospital. Walking is easy and painless. The plaster is removed after the roentgenograms show the formation of callus, usually about the seventh or eighth week. A bandage of Unna's paste prevents subsequent oedema.

Removal of the Prosthesis

The pin is removed between the third and fifth months. The extractor is indispensable.

Results

Ten patients, all adults (between thirty and sixty years of age), have been operated upon (Figs. 9-A, 9-B, 9-C, and 9-D). With the exception of one case in which the fracture was in the upper third of the leg, all of the fractures were spiral or comminuted and were at about the junction of the middle and lower thirds. We have had no opportunity to operate upon transverse fractures of the middle third. In two patients closed reduction sufficed; in eight, open operations were performed. At first, believing the osteosynthesis solid, we applied no plaster cast. The patients walked very early, with no support on the leg. The results were not satisfactory. Of five patients treated in this manner, three had perfect consolidation and two had pseudarthroses. Pseudarthrosis did not appear for a number of weeks after operation; the distal fragment with the foot turned, little by little, into external rotation. We have had to deal with fractures located near the distal end. Subsequently we adopted the method of applying an ambulatory plaster, as mentioned before. Five patients, treated in this way, obtained perfect union with no shortening and no angulation, complete function without muscle atrophy, and without the need of physiotherapy. In one case we used two pins, as certain writers advise, but this did not seem to give a better result.

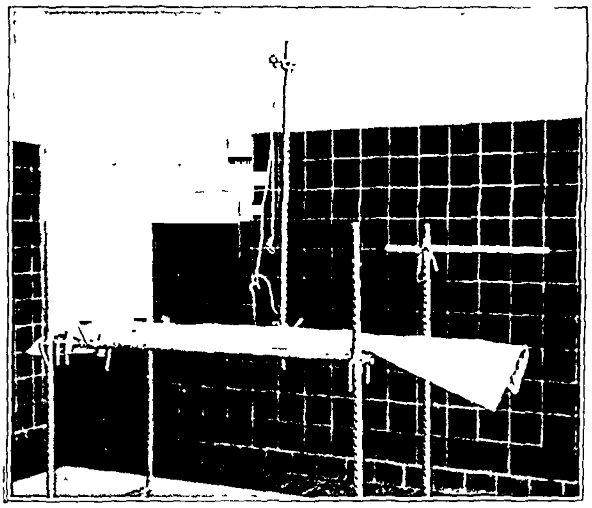

FIG. 10

The author's apparatus for reduction of fractures of the femur (Fig. 1) can be used also for pinning of the humerus. A board has been placed horizontally. One bar, 1.5 meters high, is used for traction, another to support the hand.

Indications

Medullary pinning with a curved pin, in fractures situated at the junction of the middle and lower thirds of the tibia, gave excellent results, provided that an ambulatory plaster was applied. If we compare our results with those which we obtained previously by closed methods (reduction on a Böhler frame, extension with a Steinmann pin in the calcaneus, and plaster for four to five weeks, then ambulatory plaster for six to ten weeks), we find the following advantages in favor of pinning: anatomical reduction, rapid consolidation, shortening of the period of hospitalization, better functional recuperation, since there is no atrophy of the quadriceps. One disadvantage of pinning is the presence of an operative scar, which is objected to by young girls for aesthetic reasons. This method is certainly indicated in fractures of the middle and upper thirds. Our experience does not permit us to say whether or not a plaster cast is necessary in such cases. The method is not recommended in compound fractures. For pseudarthrosis we prefer a bone graft.

THE HUMERUS

At first we introduced a curved pin by way of the olecranon fossa. We have discontinued this. We prefer the upper route, driving a straight pin into the head of the humerus, toward the elbow. We shall describe only the latter technique.

Choice of Pin

A straight pin is used, grooved in the form of a U and five to seven millimeters in diameter. The length is determined beforehand by the following method: On the sound side the distance between the lateral tip of the acromion and the olecranon is measured with the arm at the side, the elbow flexed to 90 degrees. From the figure obtained, five centimeters is subtracted.

Position of the Patient

It is impossible to reach the humeral head unless it is brought into prominence. For this, the arm should be put in flexion and in strong adduction. The patient is in lateral decubitus on the sound side. The injured arm is fixed snugly on the thorax in maximum flexion (Fig. 11).

Introduction of the Pin

In contrast with other bones, medullary pinning of the humerus is started *before* reduction. The operation is begun under brachial plexus anaesthesia, with local anaesthesia of the skin of the shoulder. A Kirschner wire is passed through the upper part of the ulna, and a stirrup is attached. In this way, skeletal traction is attained. The patient is placed in the position indicated in the preceding paragraph (Figs. 10 and 11). Where the humeral head is most accessible, a short longitudinal incision is made. The fibers of the deltoid are retracted, and the point where the tuberosity joins the anatomical neck is marked. This is the point of penetration. With a gouge, the bone is trephined. During this manoeuvre the articular capsule may be opened slightly. Through the hole in the humeral head, the guide (a steel wire, three millimeters in diameter and forty centimeters long) is forced into the medullary cavity. Roentgenograms verify the position of the guide. The pin is driven along the guide into the proximal fragment only. The guide is then removed. The situation is then the following: The fracture has not been reduced, the pin is in the proximal fragment, and a large part of it projects. (At this point, the segment of the pin which protrudes and the operative site must be well protected with sterile dressings.)

Reduction

The patient is placed in dorsal decubitus and attached to the table with straps. With a pulley, placed 1.5 meters above the level of the table and on the side opposite the fracture, progressive extension is applied through the Kirschner apparatus. The arm should be in at least 45 degrees of adduction and 75 degrees of elevation (Fig. 12). The

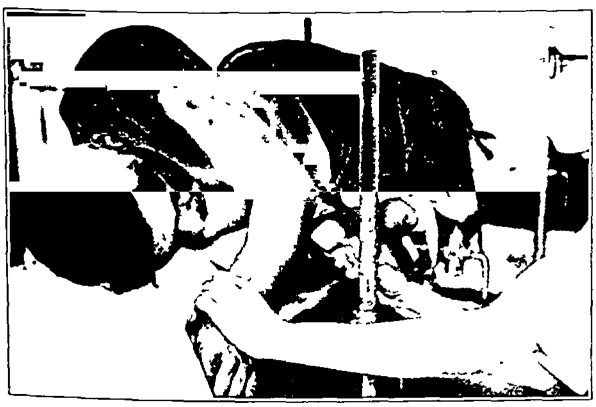

Fig. 11

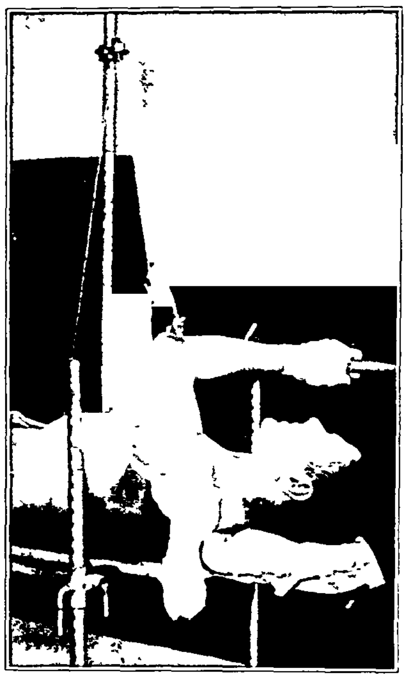

Fig. 12

Fig. 11: Diaphyseal fracture of the humerus—first step in treatment. Brachial plexus anaesthesia with patient in lateral decubitus on the sound side. Arm is in adduction and extreme flexion. Kirschner traction at the level of the ulna. In this position the humeral head is easily accessible; it forms a projection. Shows incision and placing of the pin in the proximal fragment.

Fig. 12: Second step: Reduction of the fracture, with patient in dorsal decubitus; traction, with the arm at 75 degrees of elevation and 45 degrees of adduction; elbow at right angle. Fluoroscope or roentgenograms may be used. Open operation is easy, if required. The pin, which is yet only in the proximal fragment, has been protected by sterile dressings during the moving of the patient.

elbow is flexed to a right angle. Reduction is checked by fluoroscope or by roentgenogram. Angulation is corrected by lateral slings. If anatomical reduction cannot be obtained, it may be necessary to expose the site of fracture by one of the classical incisions,—along the deltopectoral groove for the upper third, the external or internal border of the biceps for the middle third, the posterior surface of the arm for the lower third.

Osteosynthesis

The introduction of the pin into the distal fragment is simple after reduction has been obtained. It is sufficient to remove the sterile compresses and to strike a few hammer blows upon the head of the pin. At the end of the operation, the pin should not project more than five millimeters from the humerus; otherwise, it will impinge on the acromion in movements of the shoulder. After suture of the wound and removal of the Kirschner wire, no plaster cast is applied, except in fractures in the lower part of the humerus.

Postoperative Care

The fingers, the elbow, and the shoulder are moved at once. The patient is allowed up the day following operation.

Removal of the Prosthesis

The pin is removed two to four months after the osteosynthesis.

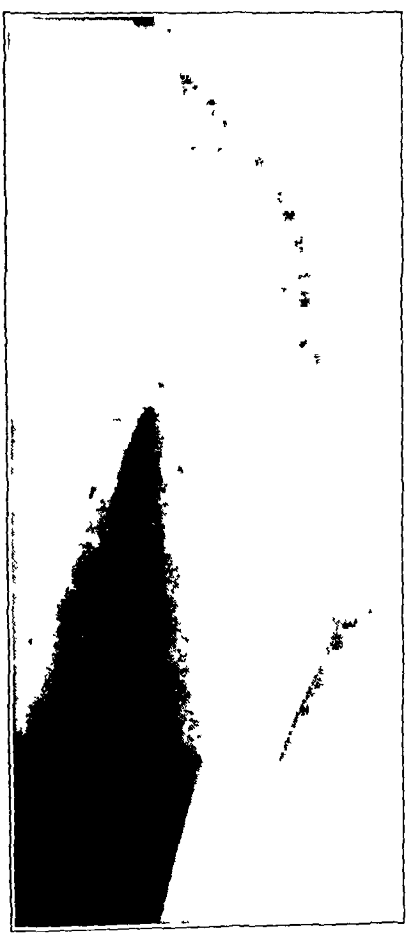

Fig 13-A

Fig 13-B

Fig 13-A: A woman of forty-eight fell in the snow and incurred an oblique fracture of the middle third of the humerus. Six days after the accident, on January 3, 1945, osteosynthesis was done, with brachial plexus anaesthesia, traction, closed reduction by roentgenographic control, incision, and trephining at the level of the olecranon fossa. Fixation was accomplished by a Kirschner wire as a guide, then by a medullary pin.

Fig. 13-B: Movement was begun at once. Photograph was taken on January 30, 1945, less than four weeks after operation.

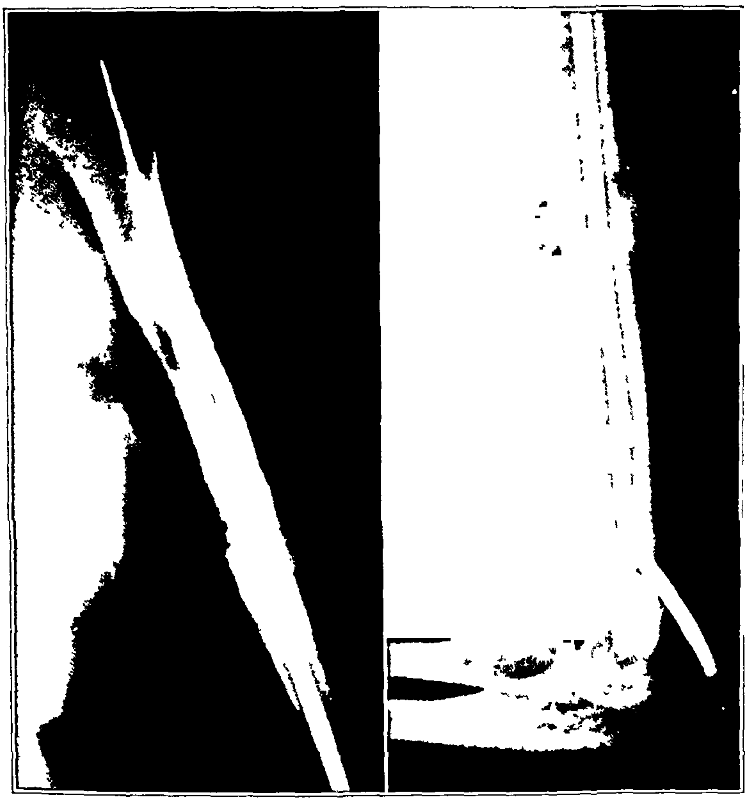

FIG 13-C FIG 13-D

Fig 13-C Six weeks after operation (February 6), solid callus was present The guide had been left in place The pin was removed in the third month The functional result (end of May 1945) was very satisfactory Abduction of the shoulder was practically normal Elbow had complete flexion, extension of 170 degrees

Fig 13-D Osteosynthesis of the humerus by the upper route in a woman eighty years old with radial paralysis A straight pin, six millimeters in diameter, was introduced in the region of the humeral head Below, it reached the inferior epiphysis Operation was performed June 13, 1945 Control roentgenograms taken July 2, 1945, showed early callus Patient is under constant treatment She can use the hand and elbow easily Active abduction of the arm exceeds 90 degrees She exercises by means of a pulley

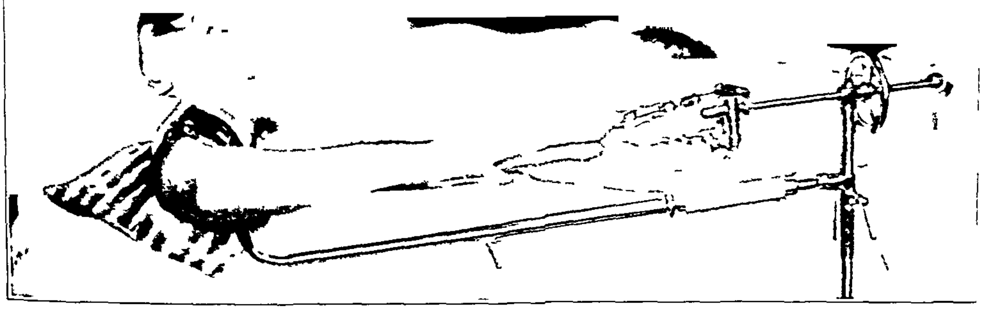

FIG 14

The author's apparatus for osteosynthesis of fractures of the forearm and closed reduction of fractures of the thumb and dislocations of the carpal bones Traction by finger cots with plaited strands Counterextension by an arm cuff Note the cushion under the arm. Photograph taken at the conclusion of pinning of the radius at the junction of the middle and lower thirds; brachial plexus anaesthesia was used In this case the incision used to reduce the fracture joined that which permitted introduction of the prosthesis

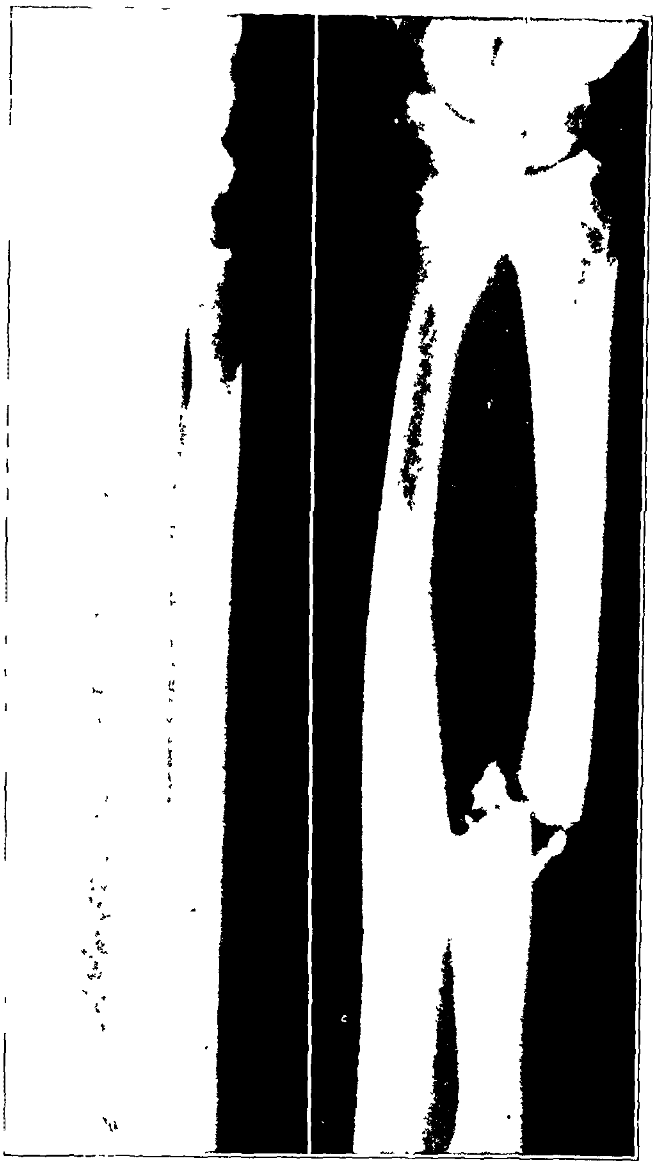

Fig. 15-A

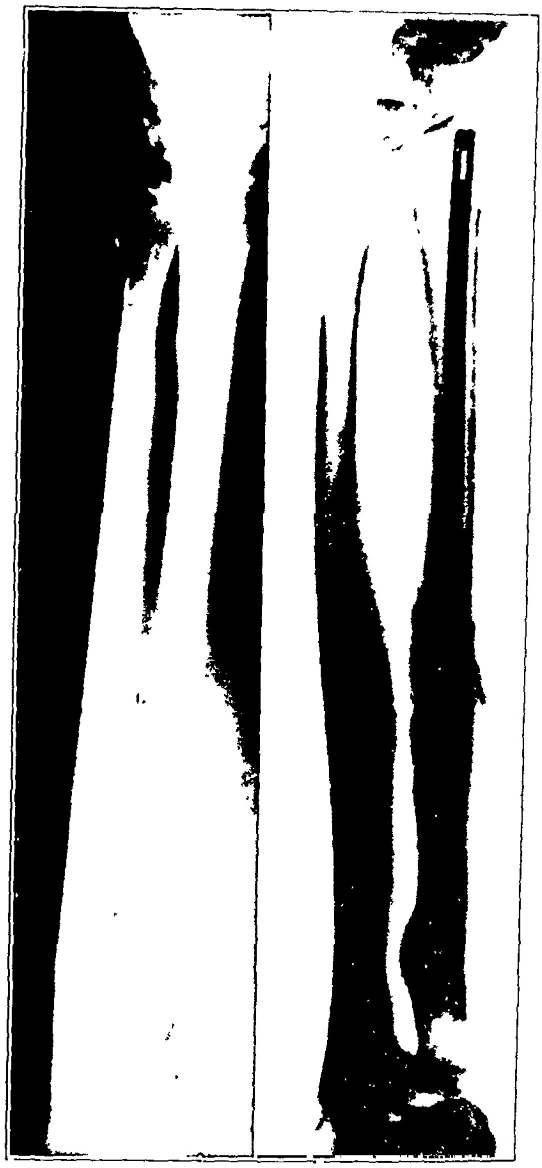

Fig. 15-B

Fig. 15-A: Transverse fracture of the radius alone, in a man of seventy-one years, who had been a victim of bombardment on May 9, 1944. Attempts at closed reduction failed. On May 19, 1944, under brachial plexus anaesthesia, traction by the author's apparatus (see Fig. 14) and open reduction were done, with trephining of the radius from the dorsal surface of the lower epiphysis. A curved pin, five millimeters in diameter, was inserted. No plaster was used.

Fig. 15-B: Ten days after osteosynthesis we entered the room unexpectedly and saw the patient eating soup, with the spoon in the right hand,—the side operated upon. Roentgenograms, taken on January 3, 1945, showed perfect callus. Grasp was normal. Pronation and supination were 120 degrees. The patient refused permission to remove the prosthesis, which did not trouble him.

Results

We have operated upon nine patients. In the first six, we used the lower route of entry,—that is, a curved pin forced through the olecranon fossa toward the shoulder. The patients ranged in age from fifteen to sixty years. Four had transverse or spiral fractures of the middle third and two had fractures at the junction of the middle and lower thirds (Figs. 13-A, 13-B, and 13-C). In three patients closed reduction sufficed; in three open reduction was required. The following results were obtained: In one patient the pin was placed incorrectly; consequently, the consolidation was due to the reduction and the plaster cast. In spite of the final good result, it was a failure of the method. The five others healed rapidly with solid callus. Movements of the hand and shoulder were perfect. Twice we found a limitation of extension at the elbow, loss of 20 degrees for one and of 25 degrees for the other. Because of this limitation of extension of the elbow and because

of the difficulty of the technique (curved pin and a difficult approach to the humerus by the olecranon fossa), we have given up the lower approach and now use only the upper approach described above. Of three patients operated upon by the upper approach, one, seventy-five years old, had Paget's disease of the humerus; one, thirty-four years old, had a spiral fracture of the middle third; one, eighty years old, had a transverse fracture at the junction of the middle and lower thirds (Fig. 13-D). Twice open reduction was carried out; in one, closed reduction sufficed. The results are recent, but very good.

Indications

The intramedullary pinning lends itself to all closed fractures of the humeral diaphysis. The upper approach with a straight pin seems preferable to the lower approach with a curved pin.

FOREARM

Open reduction is performed. At the elbow, a pin or a square rod is driven into the ulna by way of the olecranon. For the radius, a slightly curved pin or rod is introduced from the lower epiphysis.

Choice of Pin

The size of the medullary cavity of the bones of the forearm varies greatly in

Fig. 16-A

Fig. 16-B

Fig. 16-A: A woman of twenty-five was in an automobile accident on October 5, 1944. Attempt at closed reduction was unsuccessful On the tenth day, osteosynthesis was performed under brachial plexus anaesthesia, with traction by apparatus, incision over both fracture areas, and reduction. The medullary cavities were extremely narrow and permitted only the passage of fine Kirschner wires. Pinning of the ulna was done by way of the olecranon; pinning of the radius, from the lower end (incision and trephining) Plaster was applied to the forearm for three months

Fig. 16-B: Control roentgenograms, seven months after operation (May 25, 1945) showed perfect callus. In the lateral view it appeared that the wire passed into the radiocarpal articulation; the anterior view showed that the wire was superimposed; the place of perforation is in reality situated two centimeters higher than the joint line. Functional result was perfect.

patients. The radius of a robust man permits the passage of a pin five millimeters in diameter, while in a small, frail woman, a rod of 1.3 millimeters is as large as can be passed. It is often difficult to judge the size in advance, and roentgenograms are misleading. It is only during operation that one can determine the size. We always place on the table some of the V and U pins of five-millimeter diameter and rods of 1.5 to three millimeters. For these pins the length is easy to determine directly on the injured forearm. For the rods, any estimation beforehand is unnecessary.

Position of the Patient

We always operate with brachial plexus anaesthesia. The limb is placed on a special apparatus, which we devised some time ago, and which we use for closed reductions of fractures of the thumb and dislocations of the carpal bones (Fig. 14). The patient is in dorsal decubitus. The elbow is at a right angle. Traction is applied on the fingers by means of finger stalls with woven fibers. Counterextension is made on the arm, as described by the author in a paper in *Revue d'Orthopedie* in 1941.

Reduction

Experience has shown us that in the forearm, simple traction and manipulation lead to approximate, but not anatomical, reduction. Thus it may be necessary to expose the site of fracture. We follow the classical incisions. Reduction is easily obtained with the use of the periosteal elevator and the Lambotte hook.

Osteosynthesis

In fractures of both bones, we begin always with the ulna. During the open reduction, we examine the size of the medullary cavity and try the prosthesis to determine if we must use a pin or a rod. By a very small incision over the olecranon the prosthesis is introduced, care being taken to direct the pin or rod accurately. A blow of the hammer will drive in a pin of five millimeters or a rod of 2.5 to three millimeters. If a thinner rod is used, a Kirschner perforator will be required. The passing of the pin or rod from one fragment to the other is controlled by observing the fracture site. After roentgenograms have been taken, the wound is sutured. If a rod has been used, which projects from the olecranon, the projecting portion is cut with pincers. The radius is exposed in turn. An incision, five centimeters long, is made on the dorsal surface between the extensor tendons of the thumb and of the index finger. The tendons are retracted and, with a fine gouge, the cortex is trephined. A curved pin or rod is introduced from below upward. After control roentgenograms have been taken, the wound is sutured. In osteosynthesis with a pin, no immobilization is required. With a rod, one must guard against flexion at the site of fracture. A plaster cast of the forearm alone is necessary.

Postoperative Care

Whether or not a plaster is used, movements of the fingers, the elbow, the shoulder, and of pronation and supination are encouraged at once. It is surprising to see how these movements are easily performed and are painless. After ten days, the plaster cast is cut, the sutures are removed, and a new plaster is applied and worn until union is complete.

Removal of the Prosthesis

During the third month the prosthesis is removed.

Results

Thirteen patients, ranging in age from seventeen to seventy-one years, were operated upon. Therapeutically, these cases may be tabulated as follows:

1. In six cases in which pins of five millimeters were used, three were fractures of both bones, two were fractures of the radius in the middle third, and one involved the ulna in the upper third. All of these fractures healed in less than two months. The functional

result was poor in one case with synostosis of the two bones, where there was comminution of the radius and ulna. The results were very good in the other five. Function and strength in the hands were regained, pronation and supination were preserved (Figs. 15-A and 15-B).

2. Two fractures of both bones in the middle third were fixed with rods, 2.3 millimeters in diameter, with perfect results.

3. Three cases (two with fractures of both bones, one with a fracture of the lower third of the radius) were fixed with Kirschner wires, followed by a plaster cast of the forearm for seven to ten weeks. These healed normally (Figs. 16-A and 16-B).

4. Two cases were complicated. An old Monteggia's fracture, with pseudarthrosis of the ulna and an unreduced dislocation of the radial head, was treated by a medullary pinning of the ulna and resection of the radial head. The end result was good. An old crushing injury of the upper extremity with marked bowing and shortening, and with weakness of the fingers, was treated by osteotomy and pinning of the ulna. This patient had a fair result, with recovery of movements of the hand.

Indications

From our experience with thirteen patients, eight of whom had fractures of both bones, we feel that the method is simpler and gentler than closed reduction. It is technically easier than osteosynthesis with plates, which often results in pseudarthrosis. In the field of simple diaphyseal fractures of the forearm, intramedullary pinning has achieved unquestioned and definite progress, whatever may be the type or location of the fracture. We believe that this method is contra-indicated in compound fractures.

OTHER FRACTURES

We have not used pinning of the clavicle, for we believe that the pin is insufficient to support the weight of the arm. The non-operative method of reduction is superior, since it leaves no scars.

In order to place a pin in the diaphysis of a phalanx or a metacarpal bone, it must be passed through a joint. For this reason we have not used pinning in these locations.

We are putting the finishing touch to a surgical method in the treatment of intertrochanteric fractures, with intramedullary pinning as one of its principles. A report of this will be published later. This cannot be included properly in a discussion of diaphyseal fractures.

SUMMARY AND CONCLUSIONS

1. Osteosynthesis by the medullary route respects the three great principles of treatment of fractures,—reduction, fixation, and mobilization. *Reduction* must be excellent, since the introduction of the pin requires anatomical continuity of the bone canal. In *fixation,* the pin is very strong and firm, and assures a powerful immobilization of the fragments. Since it takes hold through the entire diaphysis, the forces of torsion and flexion are diffused over a wide area. Moreover, the presence of the foreign body in the soft bone accelerates the formation of callus. As to *mobilization,* the use of the limb is recovered rapidly; axial pressure favors osteogenesis and active movements avoid articular stiffness, muscle atrophy, and circulatory disturbances.

2. Experience acquired by us in fifty-five operations has demonstrated the relative simplicity of the method. It is an advance over the other procedures in present use in the treatment of diaphyseal fractures of the most important long bones of the skeleton. These procedures, in order to be successful, require either exceptional skill on the part of the surgeon or great patience and discomfort on the part of the patient. On the other hand, the method is not attended by the serious dangers which we might have anticipated from the theoretical critics.

3. We have described the technique which is recommended for each area, and we have pointed out the difficulties which have been surmounted, as in the application of any new surgical procedure.

4. The results obtained in twenty-three diaphyseal fractures of the femur, ten of the leg, nine of the humerus, and thirteen of the forearm have been analyzed critically. We have outlined the operative indications. We do not advise intramedullary pinning in compound fractures. We recommend it enthusiastically in closed fractures, especially of the femur and of the forearm, where this method gives the solution of a problem not met satisfactorily up to the present time.

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RECONSTRUCTIVE SURGERY IN PATIENTS WITH WAR FRACTURES OF THE ANKLE AND FOOT

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At Valley Forge General Hospital, members of the Orthopaedic Service have had the opportunity for over two years of observing and treating many severe foot injuries in patients who have come back from the various theaters of war. Most of the patients returned from overseas at least four to eight weeks after the occurrence of the fractures, and therefore they were usually in the intermediate phase of treatment. Thus surgery for them was not of an emergency nature. Time and care were taken to study their basic tissue defects and structural defects and to follow the progress of healing. In addition, much thought was given to planning reconstructive surgery, upon the general thesis that a living foot which has reasonable stability, sensation, and comfort, even though it may be seriously deranged, is more desirable than an artificial foot. Only two of the patients required amputation.

When a careful examination of the foot had been completed, a plan of treatment was laid out for the intermediate stage. Final reconstructive surgery might be contemplated, but the foot was often given the test of time and use before this was carried out.

If there was an open wound, the foot was soaked and bathed in sterile, warm, soapy water. The wounds were cleansed; sinuses were probed and irrigated. Loose or exposed pieces of bone and foreign material were removed. The dressing consisted of one layer of close-meshed vaseline gauze to cover the wound surface, with the usual gauze squares on top.

Next the foot was placed, as accurately as possible, in normal weight-bearing alignment under the tibia, with the ankle joint at an angle of 90 degrees. The calcaneus was placed either in a direct line or in slight inversion, but the foot itself was slightly everted. The contour of the foot and of the arches was molded into a relationship as nearly normal as possible, and plaster was applied. The cast was padded as little as possible.

The casts were changed at intervals of one, two, or three weeks, depending upon such factors as the comfort of the patient, the type of injury, and the amount of discharge. The soldiers preferred casts so that they could get up and go about, but occasionally a deep wound behaved better when the foot was elevated in bed and the dressings were changed frequently. Surface wounds healed more rapidly when exposed to the air. Weight-bearing was often begun while the patient was still in plaster, by adding a walking iron. When rigid support could be abandoned, a flexible Unna's gelatine boot or elastoplast was applied.

TRIAL STAGE

The trial stage was a period of weight-bearing in a shoe with proper support. Over a period of weeks and sometimes of months, the patient was watched to see what Nature would accomplish toward banishing the limp and restoring painless weight-bearing. One patient with bilateral fracture of the calcaneus, for example, went back to limited duty for twelve months, before he returned and said that his feet were too painful to continue such activity. Proper walking had to be insisted upon. Arch supports were frequently needed. A metatarsal bar was often helpful in fractures of the tarsus and fore part of the foot, and a Thomas heel added an element of stability and control to the shoe.

The rehabilitation program was built upon three principles:

1. Walking is the best physical therapy for an injured foot.
2. A patient cannot walk on either a swollen foot or on one without adequate shoe support.

FIG. 1-A

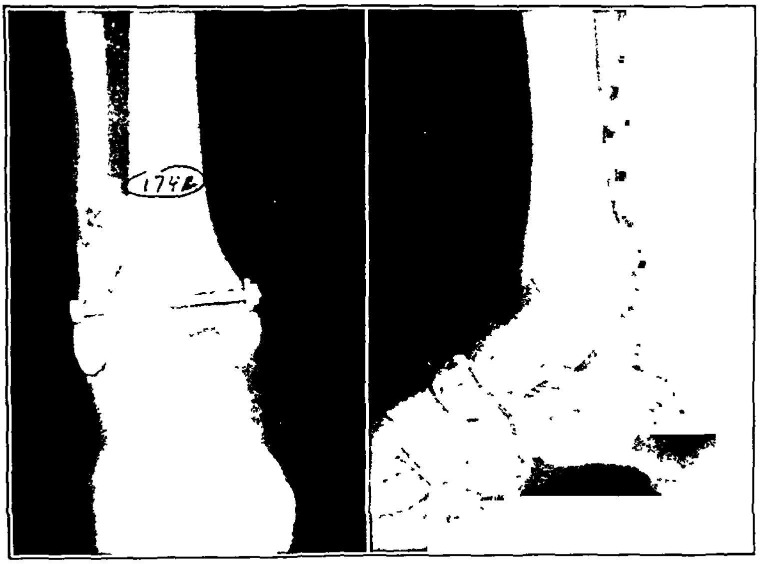

FIG. 1-B

Case 1. Private First Class A. R. W. The patient was injured in a jeep collision, in England, in March 1944.

FIG. 1-A: Shows painful unstable ankle joint, with non-union of fibula.

FIG. 1-B: Postoperative result.

3. Swelling can be prevented by adequate elastic support, or it can be relieved by elevation and exercise.

The Physical Therapy Department was of decided aid in promoting the recovery of these feet. The crusty foot with dry skin that had just come out of a cast was benefited by whirlpool baths and oil massage. The foot that was bound up with scar tissue was helped by the softening effect of the baths and manipulation. Proper walking habits were taught. The therapeutic gymnasium had a number of helpful foot exercises, which included use of the bicycle, rowing machine, inclined boards, steps, and mirror walking.

FIG. 2-A FIG. 2-B

Case 2. Captain B. P. P. (Medical Corps). This officer was injured in September 1943, when he fell from a bicycle during a black-out in England. Open reduction was performed in England after eight weeks, because of non-union.

FIG. 2-A: Screw fixation was unsuccessful.

FIG. 2-B: Union occurred after final operation, with bone graft, in March 1944.

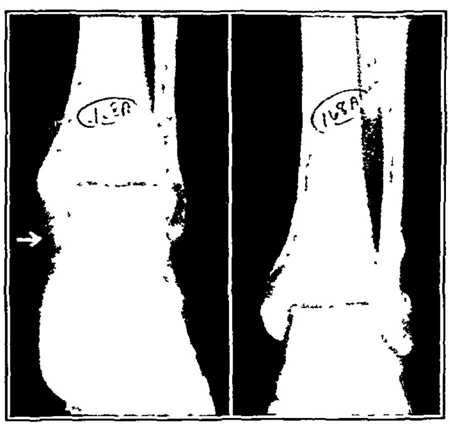

FIG. 3-A FIG. 3-B

Case 3. Private D. McC.

FIG. 3-A: A Pott's fracture of the left ankle was sustained in January 1945. There was persistent pain on dorsiflexion of the foot, caused by bony proliferation beneath the medial malleolus.

FIG. 3-B: Shows postoperative clearing.

FIG. 4-A

FIG. 4-B

Case 4. Private T. F. Patient was wounded by a mine explosion in March 1943, while riding in a jeep in Tunisia.

FIG. 4-A: Roentgenograms show severe distortion of ankle and subtalar joints and multiple fractures.

FIG. 4-B: Shows postoperative arthrodesis, with sliding bone graft.

GENERAL PRINCIPLES OF SURGERY

The objective of treatment was a painless weight-bearing foot which would carry the soldier through a useful life. To obtain this, the following basic procedures were used, alone or in combination: (1) restoration of structural continuity, where bony defects were present; (2) correction of weight-bearing malalignments; and (3) arthrodesis of joints which were painful or disintegrated.

Flexibility of the foot was secondary to good weight-bearing alignment. A painful joint was much more disabling than a stiff one. Nature was kind to this strong-muscled, youthful group and many men finally recovered fine capable feet. In general, however, a badly damaged foot proved to be handicapped, regardless of how much *could be accomplished by skin grafts,* bone grafts, joint fusions, or rearrangements of bone alignment.

A number of factors were evaluated in each case before surgery was undertaken:

1. The character of the patient was taken into consideration, in an attempt to find out whether he was making a real effort to use his foot.

2. Accurate localization by examination and roentgenogram were employed to determine the exact cause and source of the pain. The gait was carefully analyzed and the line of the weight thrust down the limb into the foot was evaluated.

3. An estimate of the operative result was made and, if there was a reasonable anticipation of improvement, surgery was advised.

ANKLE JOINT

Complications: Relaxation of the tibiofibular synarthrosis following ankle sprain or fracture was one of a number of late complications of injury around the ankle joint. In Case 1, the whole foot tended to evert and roll outward into a painful valgus position as weight was thrust upon the ankle. Operative interference was helpful in restabilizing the ankle joint. The excess of soft tissue between the two bones, which by now had become a bursa, was curetted out so that the bony surfaces came into lateral contact. Then a bolt was inserted transversely through the fibula and into the inner side of the tibia, about one-half inch above the joint. Nuts and washers were applied to bind these bones tightly together and to restore a rigid joint mortise. After eight weeks, the bolts were removed. In

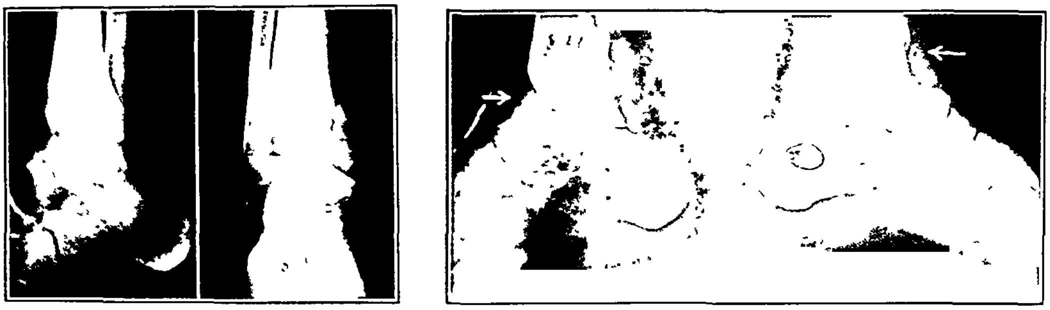

FIG. 5-A FIG. 5-B FIG. 5-C

Case 5. Sergeant N. R. Patient was wounded by shell fragment, while in Tunisia.
FIG. 5-A: Metal fragment may be seen in joint.
FIG. 5-B: After removal of fragment.
FIG. 5-C: Persistent pain made ankle fusion necessary.

this case, the added complication of non-union of the fibula was the causative factor in loosening the tibiofibular synarthrosis.

Non-Union of the Medial Malleolus: After a Pott's fracture, it was quite common to find that the medial malleolus had not formed firm bony union with the shaft of the tibia. In many of these cases there was strong fibrous union, which served adequately. Pain remained in some cases when the foot was turned inward, however; and these cases were helped by surgery. The corrective operation was not nearly so simple in these late cases as it appeared at first glance. Two or three operative failures were encountered, including one in a medical officer (Figs. 2-A and 2-B). First of all, it was quite difficult to loosen the malleolus sufficiently to bring it into good apposition with the body of the tibia. By the time this had been accomplished, much of the medial ligament had been pried off. The next step was to hold the malleolus in contact. Screws were usually inadequate, because the threads did not hold in the cancellous bone, but occasionally a long wood screw would hold. It was found better to drill a hole across the lower end of the tibia and thread a heavy wire circumferentially through it, under the malleolus. When the wire was tightened, it snubbed the little fragment into place and also left an open surface for a small sliding bone graft. In view of the operative failures, this precaution seemed an additional insurance for union.

Bony Masses or Proliferations Beneath the Malleoli: After ankle fractures, bony masses or proliferations were found either in the anterior part of the medial ligament of the ankle or laterally in the anterior talofibular ligament. Painful dorsiflexion of the foot, with a localized tender mass of bone, confirmed by roentgenogram, was the indication for operative removal. A good result was obtained in Case 3 (Figs. 3-A and 3-B).

Valgus or Eversion of the Foot: This deformity, which occurred frequently after ankle fractures, was caused by outward angulation or displacement either of the lateral malleolus or of both malleoli. It was the most common complication of inadequately reduced ankle fractures of the Pott's type. Experience with the severe deformities (Figs. 4-A and 4-B) has shown the need for extensive reconstruction of the ankle joint. Usually both malloli had to be refractured in order to restore a semblance of the normal joint mortise, and in the severe cases an arthrodesis was done because of the extensive damage to the cartilaginous surfaces of the joint.

Distortions and Irregularities in the Articular Surfaces of the Joint: These abnormalities followed fractures of the tibia or the talus, which involved the joint surfaces. In severe cases, it was evident at once that the gross distortions of the joint surfaces would result in hopelessly painful ankles. In milder cases (Figs. 5-A, 5-B, and 5-C), the damage to the joint surface, particularly that of the talus, was not so severe originally, but as

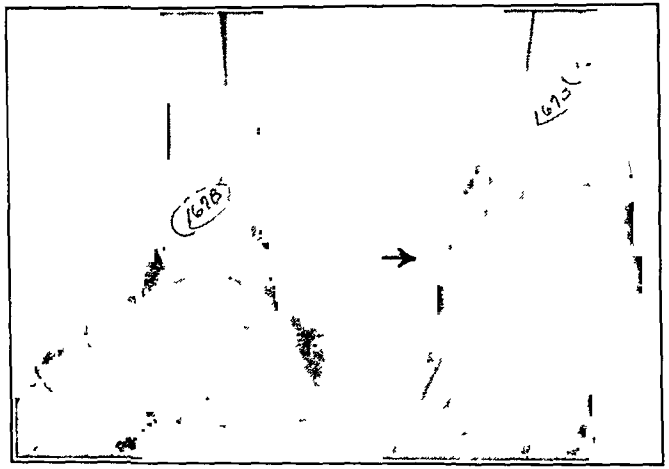

Fig. 6-A

Fig. 6-B

Fig. 6-C

Case 6. Captain C. C. (Medical Corps), a paratrooper. Wounded by machine-gun bullets during initial invasion of Sicily.

Fig. 6-A: Deformed remnant of lateral malleolus is seen above a bulge of the talus.

Fig. 6-B: Much of this mass was removed at first operation, resulting in considerable improvement. Note defect in calcaneocuboid joint.

Fig. 6-C: *After a long trial, painful instability forced the patient to request a triple arthrodesis. This was accomplished by bridging the joint defect with a* tibial graft and by building up the outside of the talus to equalize the other side.

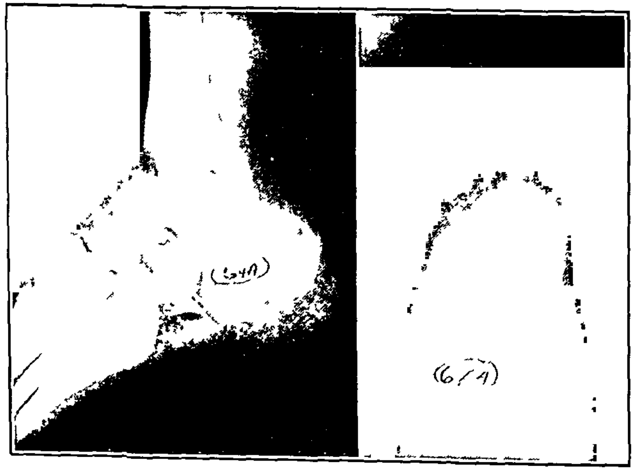

Fig. 7-A

Fig. 7-B

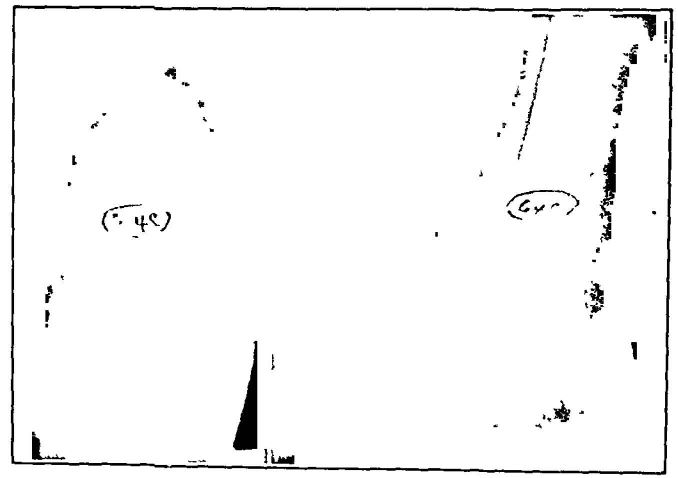

Fig. 7-C

Case 7. Lieutenant J. L. L. Injury occurred when bomb blew up deck of landing craft, on which patient was standing, during invasion of Sicily, in August 1943.

Fig. 7-A: Shows severely comminuted fracture of calcaneus, unreduced after six weeks.

Fig. 7-B: Shows postoperative fixation in a cast, with pin going through into the talus.

Fig. 7-C: Final result.

months went by the joint became more and more painful, and roentgenograms revealed further destruction of the cartilaginous surfaces. The treatment for this type of painful ankle joint was fusion of the joint. A fused ankle joint was found to be not so much of a handicap as might be expected, and the patient in this case walked without a limp.

Some of the operations were performed without a bone graft across the joint, but in most instances early fusion was made more certain by an inlay graft down the front of the tibia into a slot in the talus. The most difficult part of the procedure was to free the ligaments from the malleoli so that the talus was seated firmly against the tibia, after the cartilaginous surfaces had been removed. Care was taken to place the foot in a slightly posterior position and in 10 degrees of equinus. The graft was then cut from the front of the tibia and slid down into the receiving slot in the talus, as shown in Figure 4-B. Three or four months of plaster fixation were necessary, but a walking cast was used for the last two months.

FRACTURES AND DISLOCATIONS OF THE TALUS

These talar injuries gave disabling end results, under the best of conditions. On the Valley Forge Orthopaedic Service, there have been at least a dozen severe talar injuries. The fractures were the result of extreme violence and were often compound and comminuted. The head or body of the bone, or both, were usually dislocated. In three cases the body was dislocated backward and rotated behind the ankle joint, so that it had been impossible to reduce the fracture. Furthermore, the body usually became sclerotic because of inadequate circulation. This group of foot injuries constituted the worst cases. The distortion of the bones often was grotesque. Several of the cases were complicated by simultaneous tibial or calcaneal fractures, or both.

To restore the weight-bearing continuity of the foot without serious pain, two types of reconstructive procedure were performed:

1. *Astragalectomy* (three cases): In the first patient, the body of the talus was dislocated and dead. After excision, the clinical result was only fair. Although his foot was placed properly, so that the tibia was seated just behind the navicular, and circulation was good, the soldier still had a decided limp and some pain. The second patient (Case 8) was an officer, upon whom an astragalectomy had been performed overseas early, because of a bad dislocation and compound fracture. The result was reasonably good. With a built-up heel in a special shoe, he could walk short distances with very little limp or pain. The third patient came back from overseas with a large open wound; the talar fragments were badly

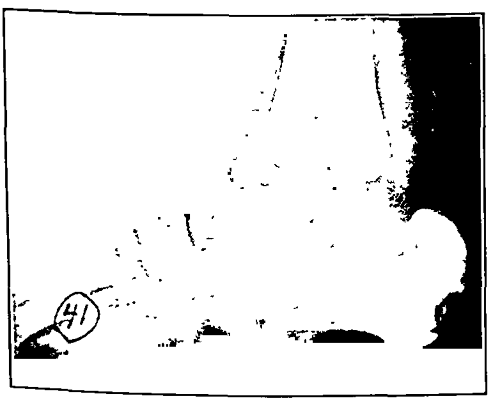

Fig. 8-A

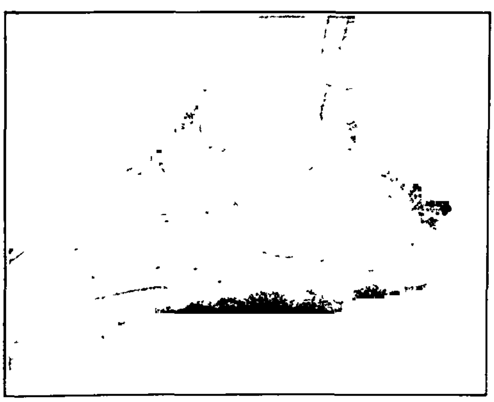

Fig. 8-B

Case 8. Lieutenant L. H. W. Patient was injured in crash of a C-47 plane in Italy.
Fig. 8-A: Roentgenogram shows the dislocation of the talus.
Fig. 8-B: Shows final position, after early astragalectomy overseas.

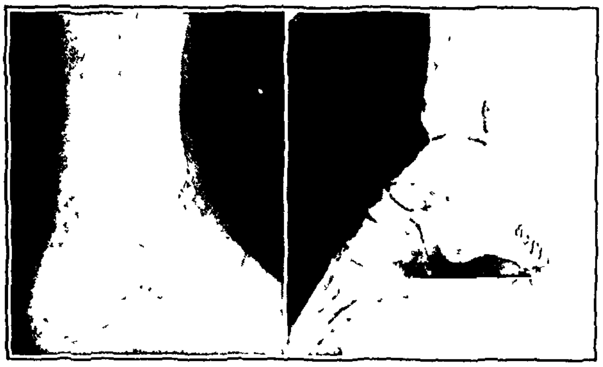

FIG. 9-A FIG. 9-B

Case 9. Sergeant F. G. Soldier was injured by shell fragment in Italy, in November 1943.

FIG. 9-A: Roentgenogram shows traumatic arthritis of subtalar joint.

Fig. 9-B: Shows postoperative fusion of subtalar joint.

FIG. 10-A FIG. 10-B

Case 10. Corporal S. O. Accidental self-inflicted gunshot wound of foot occurred, through the calcaneocuboid joint.

FIG. 10-A: Before operation.

FIG. 10-B: Shows result after triple arthrodesis.

dislocated. It was necessary to remove all of the pieces before drainage ceased. An eventual fusion between the tibia and calcaneus will probably result.

2. *Arthrodesis of the Ankle or Subtalar Joint for Double Fractures*: In several patients, including Case 4, all three bones had been involved, so that an arthrodesis of the ankle and subtalar joint was necessary. At the time of these operations, a number of questions arose. Should the sclerotic body of the talus be saved? Should tibial bone grafts be inserted to build up defective surfaces in order to equalize the alignment; or should the uneven side of the bone be removed to obtain weight-bearing stability, and thus shorten the foot? Could all of the cartilage be removed to assure fusion; or should a bone graft be slid down from the tibia, along the outer border of the neck of the talus, into the body of the calcaneus? These questions required fine surgical judgment in each individual case, and often they could not be answered until actual conditions were brought to light at the time of operation. The patients in this category had tremendous injuries and a great deal of soft-tissue damage, as well as gross distortion of structure. The foot has been preserved, but the results have been only fair.

A less severe, but complicating, injury with multiple fractures involving the lateral malleolus, the outside of the talus, the calcaneus, and the cuboid is shown in Case 6. The patient was a medical officer with the paratroopers. After the final subtalar reconstruction and fusion, he had a very satisfactory foot.

FRACTURES OF THE CALCANEUS

Many patients with severely comminuted compound fractures of the calcaneus had serious residual problems. This discussion concerns itself with three types: (1) severe unreduced fractures in which the body was so displaced that the tuber angle was grossly changed and, in some cases, was reversed; (2) those in which the fractures, irregularities, or loss of substance entered directly into the subtalar joint and frequently into the calcaneocuboid joint; and (3) those with chronic osteomyelitis of the body of the calcaneus.

1. *Unreduced Fractures*: Several of these fractures required open reduction as soon as the tissue reaction permitted and the wounds were healed. The principles of operation were twofold. First, the general alignment of the bone was restored and the fragments were molded into a contour as normal as possible; and second, a triple arthrodesis of the subtalar, talonavicular, and calcaneocuboid joints was done. Such a problem is illustrated in Case 7. Six weeks elapsed after the original injury before the patient was returned to the Zone of the Interior. The pull of the gastrocnemius had reversed the angle of the body more than 45 degrees, and what was left of the fore part of the calcaneus was severely

comminuted. At operation, the gastrocnemius had to be lengthened one and one-half inches; even then the deformity tended to recur, so that the body of the calcaneus was held down by a pin which passed through it and into the astragalus, as shown in Figure 7-B. The foot was fixed accurately in slight equinus and valgus. The final results in this case and in other cases of this type of fracture have been fairly satisfactory, in comparison with the severity of the fractures.

FIG. 11-A FIG. 11-B

Case 11. Private W. L P. Patient was wounded by shrapnel in March 1943, in Africa.

FIG. 11-A: Compound comminuted fracture of body of calcaneus resulted.

FIG. 11-B: Wound healed after radical saucerization, unroofing of cavity, and covering with skin flaps.

2. *Deformities of Joints*: The second type of follow-up problem in these calcaneal fractures was the handicapped foot which continued to be painful after a test of weight-bearing. The most common location of this pain was beneath the lateral malleolus, where it was caused by a widening of the calcaneal bulge. In one or two cases where this alone seemed to constitute the disability, a simple operation of gouging out the bulge of bone was followed by definite improvement. In the majority of instances, however, the source of the pain was demonstrated to be in the subtalar, calcaneocuboid, or talonavicular joint, or in a combination of these joints. For simple traumatic arthritis in the subtalar joint, without serious bone deformity, the Gallie operation was done, as in Case 9. This consisted of making a slot in the posterior subtalar joint, through a posterior incision, and inserting a tibial graft. For the more serious deformities, the customary triple arthrodesis was the standard operating procedure and the results were good (Figs. 10-A and 10-B).

3. *Infected Comminuted Fractures of the Body*: This problem was fairly common and was most difficult to conquer. Frequently, compound splintering injuries of the heel became infected, and the persistent low-grade osteomyelitis in the cancellous body of the bone required radical measures before it could be controlled. Case 11 illustrates the problem. After two or three ineffective sequestrectomies, a radical saucerization was performed; the top of the cavity was unroofed; and skin flaps were collapsed into the cavity. Healing then occurred.

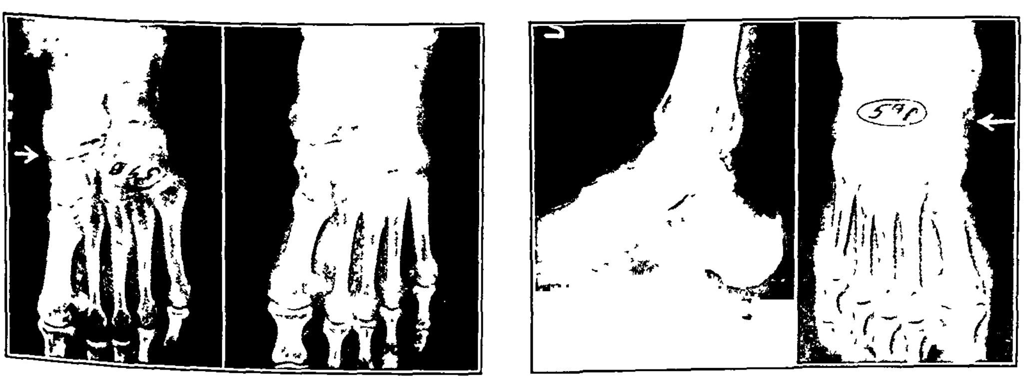

FIG. 12-A FIG 12-B

Case 12. Private P. R. Gunshot wound of foot by own rifle occurred in Africa. March 1943.

FIG. 12-A: Shows loss of most of navicular.

FIG. 12-B: Shows result after tibial bone grafts fused the space between the talus and cuneiforms.

MID-TARSAL REGION

Here, also, the problems of war surgery were somewhat different from those associated with civilian injuries. Fractures and distortions of the mid-tarsal bones in civilian life result largely from crushing injuries of the foot. In war, they come from gunshot or shrapnel wounds of the foot. At this General Hospital, such injuries were seen often in the intermediate stage, while the wound was still open and there were draining sinuses or deep open pockets into the bone; and later, in the final stage, when the wound had healed with a bad scar which first required replacement with a full-thickness skin graft. When the skin and soft tissues had healed, a period of weight-bearing was allowed to determine the exact structural weakness and the amount of pain which would develop. The circulation and the appearance of the foot improved materially with weight-bearing and exercise, but points of stress began to appear and the rough joints became painful. Roentgenograms helped to disclose the exact structural deficiency or joint irregularity.

Specific problems of the mid-foot were concerned with:

The Navicular: A deformity of the navicular, either into the talar joint or the cuneiform joints, caused disabling pain, because it was in the line of the direct weight-bearing thrust. To eliminate this, fusion across the talonavicular joint was accomplished in several cases by using a small inlay bone graft from the inner lip of the navicular. The results have been fairly good. Case 12 shows a fusion of the talonavicular and cuneiform bones (Figs. 12-A and 12-B). Where marked loss of substance of the navicular had taken place, or there was a distortion of the talonavicular joint, the calcaneocuboid joint had to be evened up in substance and a triple arthrodesis completed. Here, also, reasonably good results were obtained; in the main, the triple arthrodesis gave a good end result in those cases in which it was indicated.

The Cuboid: This bone and its joints were often affected by bullet or shrapnel wounds of the outside of the foot. There was usually so much destruction in the calcaneocuboid joint that a triple arthrodesis had to be done. In two or three instances, an added complication was the loss of bone between the remnants of the calcaneus and the cuboid, so

FIG. 13-A

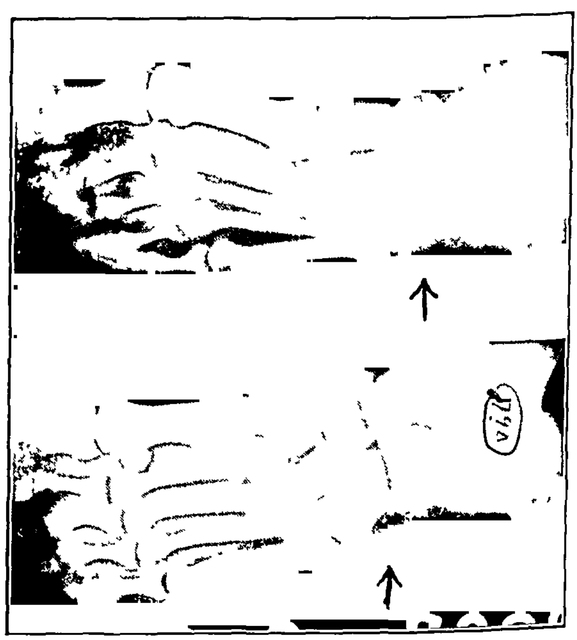

FIG. 13-B

Case 13. Private W. M. W. Patient sustained gunshot wound of foot by own rifle in foxhole in Africa, in March 1943.

FIG. 13-A: Shows defect in calcaneocuboid articulation.

FIG. 13-B: Shows fusion with bone-graft bridge.

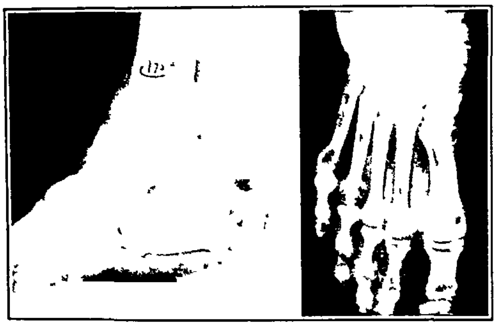

FIG. 14-A

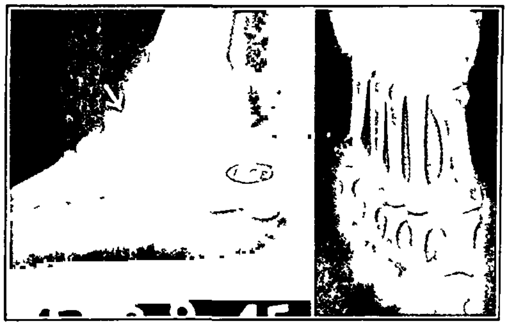

FIG 14-B

Case 14. J. S. Patient was wounded by shrapnel in Normandy, in July 1944.
FIG 14-A: Fore part of foot was flail because of loss of most of navicular and cuboid
FIG. 14-B: Shows the mid-tarsal fusion.

that the foot would have been badly shortened if the navicular had been removed or the talus had been shortened to bring them into contact. The choice in such cases was to bridge the defect with a bone graft (Fig. 13-B). The results here have also been good.

The Navicular and Cuboid: In two cases (Fig. 14-A), both of these bones were blown out in a wound across the foot; and, when the soft tissues had healed, the fore part of the foot was flail. The men walked on their heels, almost as if the fore part of the foot were missing. At operation, the scar tissue was cleaned out, the remainder of the joint cartilage was removed, and the bone remnants were beveled off and matched. The cuneiforms and the remnant of the cuboid in the fore part of the foot were brought into opposition with the talus and calcaneus. Fusion took place and the end result was a much shortened, but reasonably painless and stable foot.

The Cuneiforms: These small bones were quite often affected in mid-tarsal injuries. They sometimes fused spontaneously with each other and with the bones in front of them or behind them. In such instances the result was painless, but a number of patients had persistent bone defects with localized pain. In these instances the cavities were curetted out and filled with bone grafts from the tibia (Figs. 15-A and 15-B).

FIG 15-A FIG 15-B

Case 15 Private J. M H Soldier sustained wound of foot by own rifle in Tunisia, in January 1943
FIG 15-A: Painful arthritis resulted from destruction of middle cuneiforms
FIG 15-B Shows postoperative fusion of cuneiform area, with bone graft

Case 16 Private W. W. Q. Wound of foot was received when patient's own rifle discharged, while he was asleep, August 1943, in South Pacific FIG 16 Shows defect in first metacarpal, bridged by bone graft

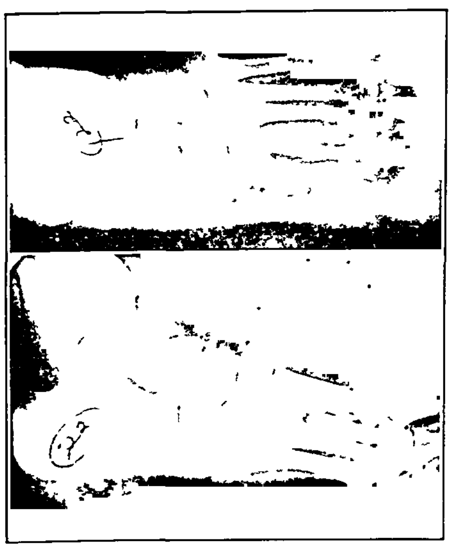

FIG 16

FORE PART OF FOOT

The fore part of the foot, with its long trail of disabling injuries, could never be treated lightly in the Army. According to a standard of usefulness to the Army, the results of all real injuries to the metatarsals and toes were disappointing. Therefore, it is evident that Army duty places a heavy strain on the foot.

The Metatarsals: In our experience, multiple metatarsal fractures usually left a painful foot, as far as military duty was concerned. Just what type of surgery to recommend for the painful end results of these fractures was a problem. In one or two instances where there was a definite localized arthritis of a proximal joint, fusion produced a fair result This procedure could be recommended, provided due care was exercised in the selection o cases, but one had always to determine beforehand whether he could avoid surgery and by shoe modifications, obtain a reasonable functioning of the foot.

In a number of instances, gross defects in the metatarsals had to be overcome. Los of substance in the first or second metatarsal was made up by bone grafts, as in Case 16 Gaps in the third and fourth metatarsals were usually left unfilled. The base of the fiftl metatarsal, if present, was sufficient for good weight-bearing. Pain-producing deformitie of the metatarsal heads were corrected, usually by resecting the offending spurs or bump carefully but generously. If the whole head had to be resected, the shaft was also taker off well back toward the base. Deep scars were most troublesome in this region.

The Toes: A great many days were spent in Army hospitals because of injuries to th toes. In retrospect, it would seem that far too much time and effort had been devoted tc the rehabilitation of little toes. They should have been amputated early, if this procedure was indicated. The big toe presented a serious problem when chronic infection set in which kept the bone draining for months and also involved the joints.

To clear up this chronic osteomyelitis, it was found necessary to watch closely and tc curette out sequestra as early as possible. As soon as the infective process cleared, the residual problem was evaluated. Sometimes the principal handicap was a sensitive scar, and the end of the toe could be partially amputated in order to get enough good skin to cover the scarred area. If the proximal joint became ankylosed or painful, the operation of choice was the Keller procedure, in which the base of the first phalanx was resected. If the interphalangeal joint was involved, the joint surfaces were curetted, so that they would fuse.

SUMMARY

A large number of patients with severe, complicated fractures of the ankle and foot returned from overseas to Valley Forge General Hospital. The reconstructive bone surgery on these cases was interesting and instructive, but often it was only one phase of rehabilitation. Surgery itself could meet the following structural demands: restoration of bone defects by grafts, correction of malalignments by osteotomies, and elimination of painful joints by fusion. The final results were difficult to classify and compare, except on an individual basis. The general impression was that they were satisfactory, considering the severity of the injuries.

THE USE OF PEDICLED MUSCLE FLAPS IN THE SURGICAL TREATMENT OF CHRONIC OSTEOMYELITIS RESULTING FROM COMPOUND FRACTURES

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Perkins states that infection of the bone is an almost inevitable sequel to a penetrating wound associated with a fracture. The inflammation is unlike that caused by blood-borne organisms in that local symptoms and general toxaemia are both less, probably because, from the very beginning, there is free drainage from the broken bone.

This osteomyelitis usually pursues one of two courses. Either (1) it clears up within a short time with adequate treatment; or (2) it resolves itself into chronic osteomyelitis, with a draining sinus leading through the soft tissues to the skin. A few cases may persist as acute osteomyelitis. In some patients the infection may heal, but have recurrent acute episodes. Some of the patients with chronic osteomyelitis may also have acute attacks.

It is with the cases which resolve themselves into chronic osteomyelitis, with a persistent draining sinus, that this paper is concerned. Such cases present problems which are dealt with at an Orthopaedic Unit.

A draining sinus usually indicates: (1) the presence of a foreign body or a sequestrum; or (2) the continuation of a chronic infection of bone. The roentgenogram is helpful in determining the presence of a sequestrum or a foreign body; but occasionally the foreign body is not radiopaque, and small sequestra may sometimes be difficult to detect by roentgenogram. Chronic infection of bone is often associated with the presence of sequestra and of abscess in the affected bone, either alone or in combination. All of the cases reported were of chronic infection of the bone, and the surgical treatment included removal, or attempted removal, of the involved part. No case of simple removal of a sequestrum or foreign body is included.

A series of cases in which pedicled muscle flaps were deliberately rotated into osteomyelitic cavities, following surgical attack on the involved bone, were studied and compared with a series of cases given similar surgical treatment, without the use of muscle transplants. In all of the cases reported, the wounds were closed at the time of surgery.

The following attempts at filling the bone cavity left by a surgical attack on chronic osteomyelitis have been reported:

1. Transplants of free fat have been used by Dunn, Forrester, and Leonte.
2. Plastic methods of closing osteomyelitic cavities by the use of skin and soft tissue have been described by Lord.
3. Sterilized and pulverized resected bone was used by Henschen, following subperiosteal resection.
4. The use of muscle flaps and muscle transplants has been discussed by Avelino and Alberto Gutierrez, by Marques, and by Stotz.

Dickson and his associates and Key reported favorable results in the surgical treatment of chronic osteomyelitis by the use of sulfonamides, generally and topically, and primary wound closure. The results with the technique described here have not been so good as theirs, in spite of the added advantage of a generous supply of penicillin.

SURGICAL TREATMENT

Group A: Use of Pedicled Muscle Flaps

There were thirty-two patients in this group. All had chronic osteomyelitis as a result of a penetrating wound and a compound fracture which had a draining sinus to the skin. The usual history was that, since the patient had been wounded, there had been a con-

tinuous discharge of purulent matter from the involved part. The time interval between injury and the operative procedure varied from four to ten months; in two cases it was twenty-seven and twenty-eight years. In a few cases the wound had been closed for short periods of time in the past.

Preoperative Preparation

Blood transfusions were used in many cases in which the plasma-protein level and hemoglobin had become lowered as a result of prolonged infection of bone.

Sodium penicillin was injected intramuscularly. The dosages varied from 15,000 to 25,000 Oxford units, every three hours. The injections were started forty-eight hours before operation and were continued for periods varying from five to fourteen days after operation. The author favors giving 25,000 units for from seven to eight days, by either intermittent injection or continuous intramuscular drip.

Some information was gained by the preoperative injection of the draining sinus with iodized poppy-seed oil, and by roentgenograms. It was also thought that methylene blue, injected twenty-four hours before operation, was of some value during the actual operative procedure. It was not used, of course, when radiopaque oil had been utilized.

Operative Procedure

1. Careful excision of the sinus tract and of the involved soft tissue is important.
2. Fairly radical attacks on the involved bone are deemed necessary. A moderately large amount of bone was removed in every case in an effort to eradicate the focus, to drain any abscesses that might be present, and to remove all sequestra. This sometimes necessitated the removal of a small amount of normal bone.
3. The whole wound is then washed with large amounts of normal saline solution or dilute penicillin solution, in a strength of 1 to 250. Penicillin cream and a 50 per cent. mixture of sulfanilamide-sulfathiazole powder are swabbed generously into the entire wound.
4. A muscle transplant, with a pedicle attached to the main muscle, is then prepared from a muscle which is most convenient to the osteomyelitic cavity. This is a relatively simple procedure, although a knowledge of the innervation and the blood supply of the muscle being used is essential. Since most of the muscles associated with the long bones pursue a longitudinal course, the transplant may be prepared from a proximal or a distal direction. It is best to have the pedicle as close to the involved bone as possible. The muscle flap is prepared to approximate the size of the bone defect, and it is then directed into the cavity. Severe twisting or angulation of the muscle is to be avoided. It is not necessary to anchor the muscle to the bone with sutures.
5. The soft tissues are then closed, if possible, and the skin is approximated with interrupted silkworm sutures, without drainage.
6. A plaster-of-Paris cast is then applied.

Postoperative Care

Penicillin is continued for periods varying from five to fourteen days, as mentioned previously. The plaster cast is usually removed in two weeks and the wound is inspected.

TABLE I

Bone Affected	Number of Cases	Number Which Remained Closed After Surgery
Femur	10	9
Tibia	12	9
Humerus	8	7
Ilium	2	2
Totals	32	27

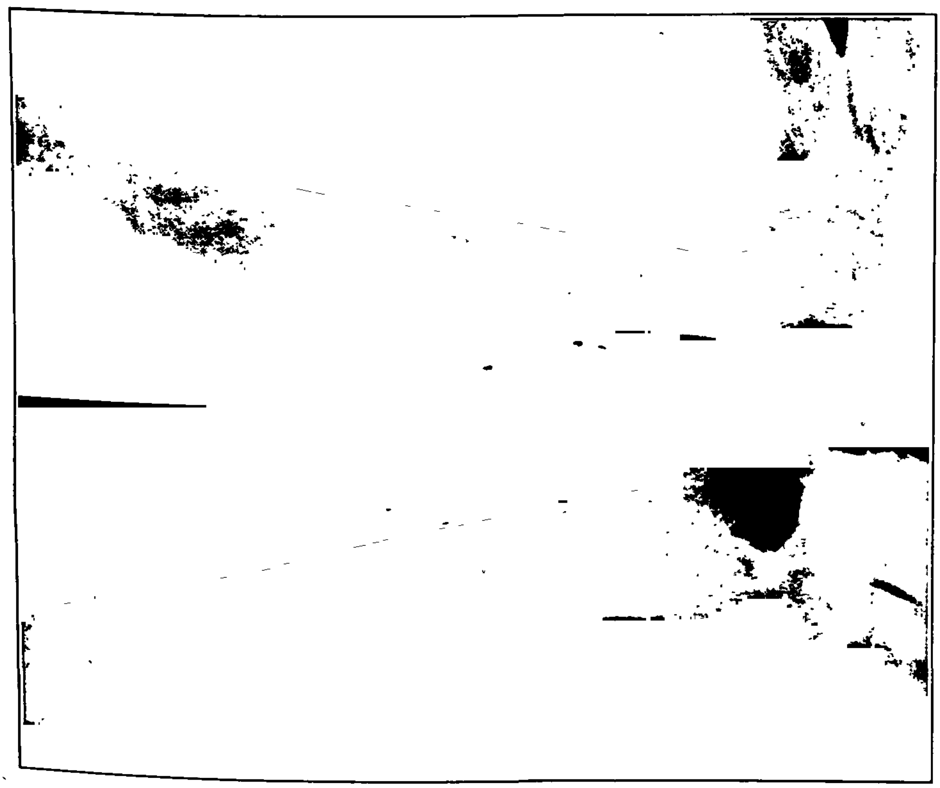

FIG. 1-A FIG. 1-B

Case 2. Right humerus, before operation.
Fig. 1-A: Anteroposterior view.
Fig. 1-B: Lateral view.

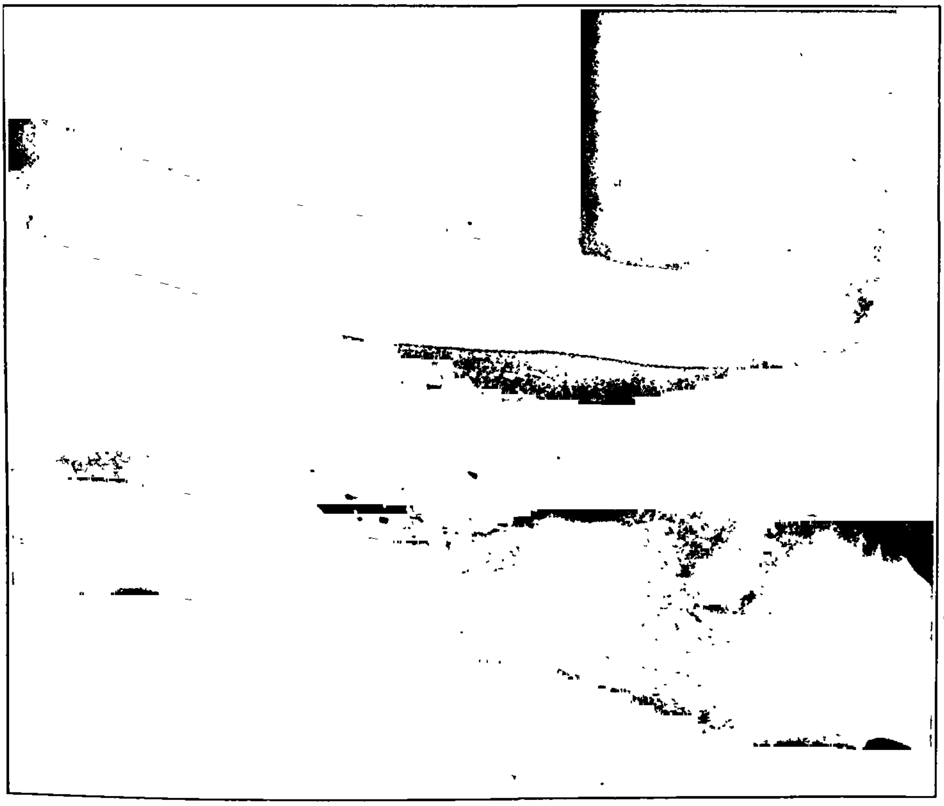

FIG. 1-C FIG. 1-D

After operation.
Fig. 1-C: Anteroposterior view.
Fig. 1-D: Lateral view.

Results

Of the thirty-two wounds which were handled in this manner, twenty-seven, or 84 per cent., have remained closed (Table I).

Bacteriology

In many of the cases there had been contamination with penicillin-resistant organisms, such as *Bacillus proteus, Bacillus pyocyaneus,* coliform organisms, including *Bacillus coli,* and some hemolytic streptococci (which were proved to be resistant to penicillin by special testing). These bacteria were present in wound cultures, in addition to the organisms which are considered to be susceptible to penicillin. Of the twenty-seven patients whose wounds remained closed after surgery, the preoperative cultures on twenty-three (85 per cent.) revealed the presence of one or more organisms of the penicillin-resistant group. In the five patients whose wounds did not remain closed after surgery, penicillin-resistant organisms were found in three cases, or 60 per cent.

Group B

This group of forty cases was reviewed for comparison with Group A. Both groups were handled and treated surgically in an identical manner, except that no deliberate muscle flap or transplant was rotated into the osteomyelitic cavity. In eight cases in Group B, a rubber tube was left in the wound for penicillin irrigations. The author's experience with this method of treatment has not been favorable.

Results

The results are shown in Table II.

TABLE II

Bone Affected	Number of Cases	Number Which Remained Closed After Surgery
Femur	16	6
Tibia	14	6
Humerus	6	4
Radius	2	1
Pelvis	2	0
Totals	40	17

The wounds remained closed after surgery in 43 per cent. of the patients.

Bacteriology

Of the eighteen patients in this group whose wounds remained closed following surgery, penicillin-resistant organisms were cultured in five instances, or 28 per cent. In the twenty-two cases which did not remain closed, penicillin-resistant organisms were found in fifteen cases, or 68 per cent.

A few favorable cases are reported. All are from Group A and were treated by the method described; muscle flaps were used in the cavities of the long bones.

CASE REPORTS

CASE 1. R. W., a white male soldier, aged twenty-five, sustained a compound fracture of the left humerus on July 23, 1943, from machine-gun fire. On physical examination he had union of the fractured humerus, clinically and roentgenographically, but he had a draining sinus on the posterolateral aspect of the arm at the junction of the upper and middle thirds, in the region of a partially healed scar. Several sequestra were seen by roentgenogram. A culture contained *Bacillus proteus* and *Staphylococcus aureus.* An operation on the sinus tract, scar tissue, and bone was performed in December 1944. A muscle flap from the triceps muscle was rotated into the bone cavity. The wound healed in ten days. Six and one-half months later there was no recurrence of the disease.

CASE 2. A. B., a white male, aged fifty-five, was injured in 1916 by shrapnel. He had a compound fracture of the right humerus with resultant chronic osteomyelitis. The wound had been draining intermittently since the injury, and had never been closed for more than three months. Physical examination revealed a draining sinus on the medial aspect of the lower humerus, which was the center of a three-inch scar (Figs. 1-A and 1-B). *Staphylococcus aureus* and *Bacillus coli* were cultured. At operation in May 1945, a muscle flap, which was attached to the triceps muscle, was used in the osteomyelitic cavity. The wound had healed when the plaster was removed, in eighteen days (Figs. 1-C and 1-D). Three months later, the wound was still closed.

CASE 3. H. F., a white male soldier, aged thirty-four, was injured in May 1944 by shrapnel, and sustained a compound fracture of the upper humerus and scapula. The wound had never been closed. Physical examination disclosed a draining sinus on the anterolateral aspect of the upper third of the left humerus, in the center of a four-inch scar (Fig. 2-A). *Staphylococcus aureus* was obtained on culture. At operation, in October 1944, a flap of deltoid muscle was used in the bone cavity. The wound had healed in ten days, and there was no recurrence in eight months (Fig. 2-B).

CASE 4. G. A., aged thirty-two, a white male soldier, was injured in May 1944, and sustained a compound fracture of the right tibia with resultant chronic osteomyelitis. Physical examination revealed a draining wound on the anteromedial aspect of the middle third of the right tibia (Fig. 3-A). A culture contained *Staphylococcus aureus* and *Bacillus coli*. Operation was performed in February 1945, and a muscle flap from the soleus was used in the bone cavity created (Fig. 3-B).

CASE 5. A. H., a white male soldier, aged twenty-five, sustained a compound fracture of the left tibia in June 1944, due to shrapnel. Physical examination disclosed a draining sinus on the anteromedial aspect of the left tibia. Hemolytic streptococci and diphtheroids were present on culture. Operation was performed in March 1945; a muscle flap from the soleus was used in the osteomyelitic cavity. The wound healed in three weeks and there had been no recurrence in four months.

CASE 6. E. M., a white male soldier, aged twenty-three, sustained a compound fracture of the right tibia in August 1944, from a shrapnel wound. This wound had never been completely closed since the injury occurred. Examination revealed a draining sinus and a wound on the anterolateral aspect of the upper third of the right leg (Figs. 4-A and 4-B). A culture was positive for hemolytic *Staphylococcus*

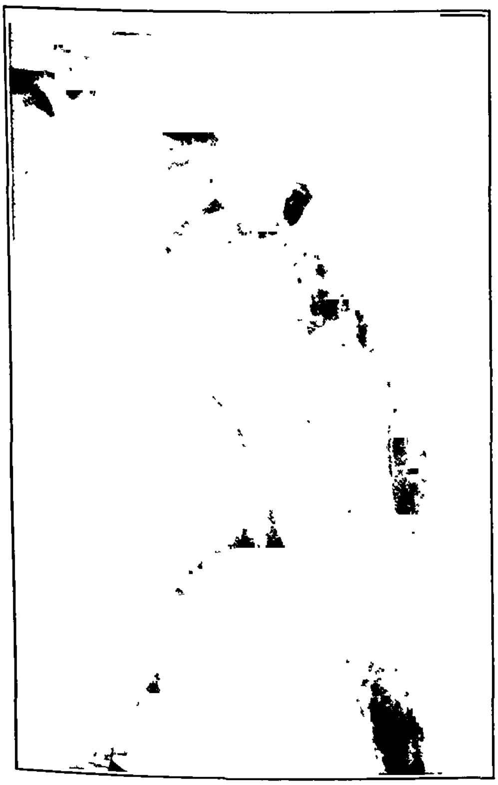

FIG. 2-A
Case 3. Left humerus. Before operation.

FIG. 2-B
After operation.

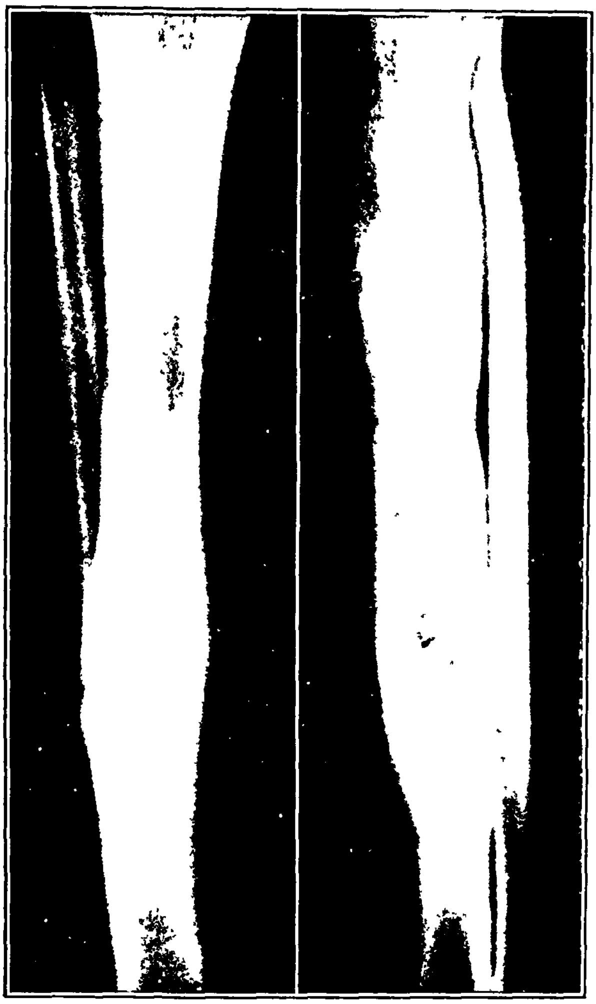

FIG. 3-A

Case 4. Right tibia. Before operation.

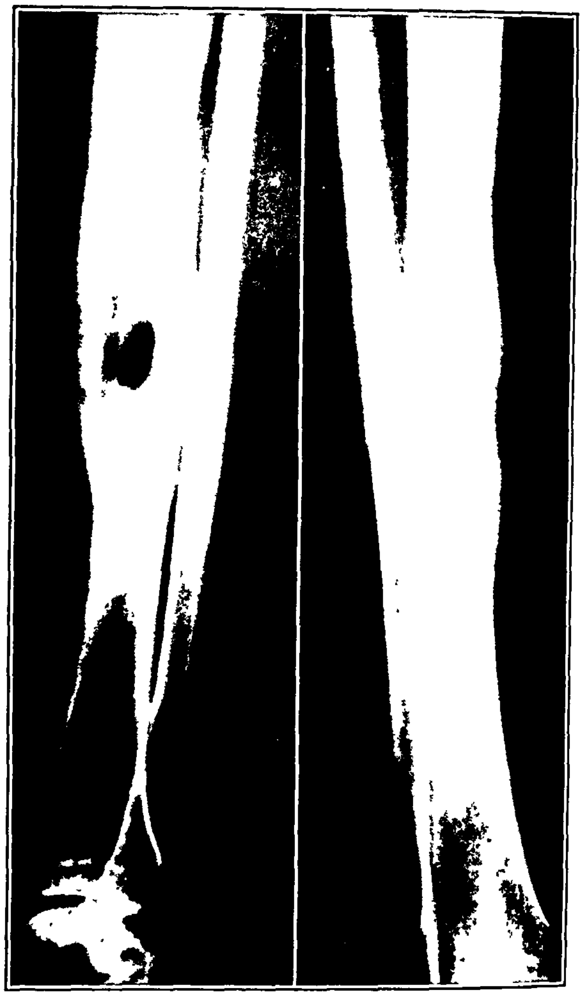

FIG. 3-B

After operation.

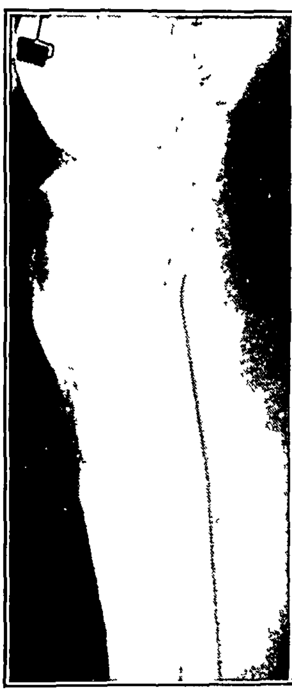

FIG. 4-A

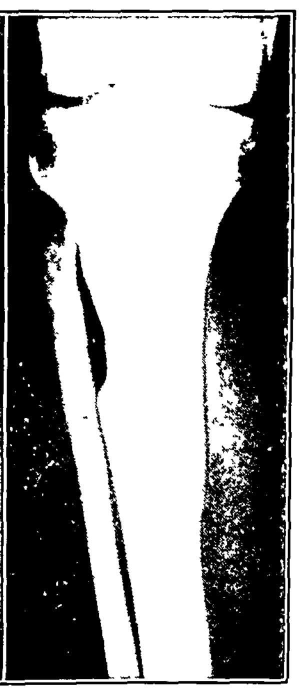

FIG. 4-B

FIG. 4-C

Case 6. Right tibia.

Fig. 4-A: Anteroposterior view before operation. Fig. 4-B: Lateral view before operation.

Fig. 4-C: Lateral and anteroposterior views after operation.

albus and *Bacillus proteus* At operation, in April 1945, a muscle flap from the tibialis anterior was used in the cavity (Fig 1-C). The wound healed in sixteen days, with no recurrence of drainage.

CASE 7. L D., a white male soldier, aged twenty-eight, received a shrapnel wound of the left femur in September 1944, and sustained a compound fracture Examination revealed that the fracture had healed clinically. (This was confirmed by roentgenogram) There was a wound and a draining sinus on the medial aspect of the lower third of the thigh. It had drained constantly since he had been wounded *Bacillus proteus* and diphtheroids were present on culture Operation was performed in April 1945, and a muscle flap from the vastus medialis was used in the osteomyelitic cavity. The wound healed in three weeks with no recurrence in four months

CASE 8 C L, a white male, aged fifty-five, sustained a compound fracture of the right femur in 1918, with osteomyelitis He had had intermittent drainage from a sinus on the lateral aspect of the thigh since that time Examination revealed a draining sinus on the lateral aspect of the middle third of the right thigh. A culture was positive for *Staphylococcus aureus* and *Bacillus pyocyaneus*. At operation, in December 1944, a muscle flap from the vastus lateralis was used Plaster was removed in twenty days, and at that time the wound had healed There had been no recurrence in six months

CASE 9. H.H, a soldier, aged twenty-five, sustained a shrapnel wound in January 1944, which resulted in compound fracture of the right femur with resultant chronic osteomyelitis Examination revealed a draining sinus on the posterolateral aspect of the region of the greater trochanter *Staphylococcus aureus* and *Bacillus pyocyaneus* were obtained on culture Operation was performed in January 1945, and a muscle flap from the gluteus maximus was rotated into the cavity The wound healed in fourteen days, with no recurrence in six months

CASE 10 G.H, a white male soldier, aged twenty-nine, was injured in December 1943 by machine-gun fire, and sustained a compound fracture of the left ilium Examination revealed a draining sinus and an old wound on the lateral aspect of the right iliac crest Staphylococci, both hemolytic and non-hemolytic, were obtained on culture. Operation was performed in January 1945, and a portion of the gluteus medius was placed in the cavity produced. The wound healed in twelve days; no recurrence had taken place in six months

USE OF MUSCLE TRANSPLANTS

Femur: The femur is covered by muscle in all of its middle third, most of its lower third, and part of its upper third. If the focus of infection is in the middle or lower third, either the vastus medialis, the vastus lateralis, or the vastus intermedius may be used. It is easier to design a pedicled muscle flap from the vastus lateralis or the vastus medialis than from the more closely adherent intermedius, which is usually involved in the infectious process In the upper third of the femur, portions of the vastus lateralis, the gluteus maximus, and the tensor fasciae latae are available for transfer, depending upon the location of the focus.

Tibia: Difficulty arises here, since the easiest exposure to the bone is through an anteromedial incision, and in many cases the osteomyelitis involves the anterior cortex of the tibia. This obstacle can be overcome by removing additional bone from either the medial or the lateral border of the tibia, as the case dictates. In this manner a muscle flap can be placed in the cavity. Thus in the upper three quarters of the tibia, a portion of the tibialis anterior can be used from the anterolateral site; from the posteromedial site, the medial head of the soleus is available. In the lower quarter of the tibia, it is somewhat difficult to use a pedicled muscle flap because of the lack of available muscle.

Humerus: In the upper half of the humerus, the deltoid muscle is used. The triceps has been used in practically all positions in this bone.

General Considerations

It must be emphasized that a knowledge of the nerve and blood supply of the muscle to be used is necessary, and that the muscle flap should have a connection with the main muscle through the pedicle. Transfers of free muscle are not recommended. No serious disturbance of function has resulted from the use of a portion of the main muscle for this purpose.

The procedure is flexible. At times the muscle of choice is involved in the chronic inflammatory process and a transplant from another muscle in the vicinity can be used.

DISCUSSION

The author agrees with Key's statement that: "In chronic osteomyelitis, continuous administration of the drug over a long period will lessen the amount of discharge, but it will not cure the disease, because it cannot sterilize dead bone or cavities with necrotic contents and rigid walls". The problem is a mechanical one and it is felt that, besides the necessity of removing dead and infected bone and soft tissue, it is equally important to deliberately fashion a muscle flap and place it in the bony defect created, if elimination of the focus of infection and of the draining sinus is anticipated.

In some positions the use of a pedicled muscle transplant in an osteomyelitic cavity is impossible, either because the muscle has been involved in the disease process, or because it is normally too distant from the part. However, the method has a wide application.

The favorable results following the use of muscle in bone after adequate surgery cannot be attributed alone to the use of penicillin, administered systemically or used topically. Penicillin will diminish the possibility of spread of infection by penicillin-sensitive organisms and would seem to have favorable effects on the same organisms when used locally, if it is directly in contact with these bacteria.

CONCLUSIONS

1. The use of pedicled muscle flaps in the surgical treatment of chronic osteomyelitis is a useful procedure, since 84 per cent. of the wounds remained closed after operation. In cases treated identically, except that a muscle transplant was not rotated into the osteomyelitic cavity, only 43 per cent. of the wounds remained closed after operation.

2. The use of pedicled muscle flaps is recommended in the surgical treatment of chronic osteomyelitis from any cause, and its application is certainly not limited to chronic bone infection following gunshot wounds and compound fractures.

3. Muscle which has been deliberately placed in osteomyelitic cavities at the time of surgery would appear to have a favorable effect on penicillin-resistant organisms. In twenty-three out of twenty-seven cases which were contaminated with such bacteria, or 85 per cent., the wounds remained closed.

4. No significant disturbance in muscle function was observed after the use of a portion of the main muscle to obliterate the bone cavity which had been created surgically, and no serious untoward reactions occurred locally or generally from the closure of these wounds.

NOTE: The author is indebted to Dr. Jack Naden, consultant to the Orthopaedic Unit, for his advice and encouragement in the use of the procedure which has been described; and to Wing-Commander R. Robertson, for permission to publish this article.

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CONDYLAR MOVEMENT IN THE STUDY OF INTERNAL DERANGEMENT OF THE TEMPOROMANDIBULAR JOINT

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The normal advance of each mandibular condyle beneath the articular eminence or anterior to it is synchronous and equal when the mouth is opened, as is its retreat into its socket when the mouth is closed. Because the condylar advance is equal and even, the chin does not shift to either side. The joint moves soundlessly. The two condyles act as a unit, since the mandible is shaped like a horseshoe.

The condyle normally leaves its socket when the mouth is opened between one-quarter of an inch and three-quarters of an inch, but it remains within the limits of the capsule of the joint. This may be called a dislocation, if comparison is made with the behavior of other joints (Figs. 1, 4-A, and 4-B). Hence, it may be said to be the only joint which dislocates normally. The average mouth opening does not exceed one and three-quarters inches, and two inches or more is unusual. The angle of the jaw, by indirect or lever action, controls mouth opening. The angle must be obtuse for good opening; the average angle is between 120 and 130 degrees. The angle of the jaw is significant mechanically in the forward thrust of the condyle in opening the mouth. A lesser angle means less thrust in mouth opening, and a greater angle forces the condyle more easily under the eminence (Table I).

TABLE I

CORRELATION BETWEEN ANGLE OF THE JAW AND MOUTH OPENING IN THE NORMAL INDIVIDUAL

Sex	Age (*Years*)	Angle of Jaw (*Degrees*)	Mouth Opening
Male	20	108	1¾ inches
Male		130	1¾ inches
Male	26	128	
Male		110	1⅝ inches
Female		116	
Male		130	
Female		120	⅞ inch
Male	61	120	1¾ inches
Female	9	132	Good
Male	21	125	1¾ inches

Asynchronous condylar movement produces unequal condylar advance. The more rapidly advancing condyle causes a shift of the chin to the opposite side, which is corrected only when the slower condyle reaches an anterior position equivalent in distance to that of its faster mate. If the slower condyle cannot move as far anteriorly, the shift persists. The retreat of each condyle is different, as the mouth is closed. The less forward condyle retreats into its socket first, since it goes a shorter distance. Deviation of the chin persists or is increased until the other, more anteriorly placed, condyle enters its socket. The shift of the chin is always *away* from the side of greater condylar motion, and does not indicate *per se* the side which is involved.

Normal lateral motion of the jaw is equal in range and involves the advance (anterior motion) of one condyle with the synchronous retreat (posterior motion) of the other. It is important to remember this in considering the inequality of lateral movement by meniscal derangement (Fig. 1). If the advance of one condyle has been stopped by meniscal block, the synchrony of lateral movement is disturbed. Lateral motion is greater *toward* the side of involvement, since the normal condyle can advance and retreat, while the affected condyle cannot move forward (Figs. 2-A and 2-B). If the retreat of the condyle has been blocked, the greater lateral movement is *away* from the side of involvement (Figs. 3-B and

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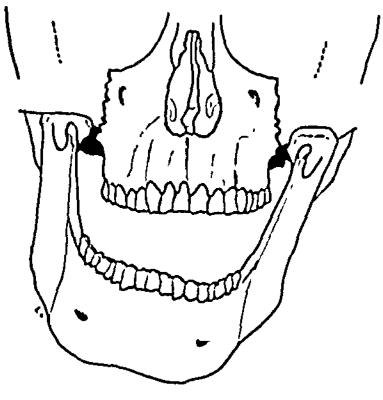


Fig. 1

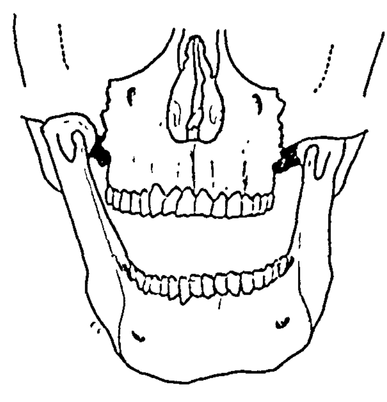


Fig. 2-A

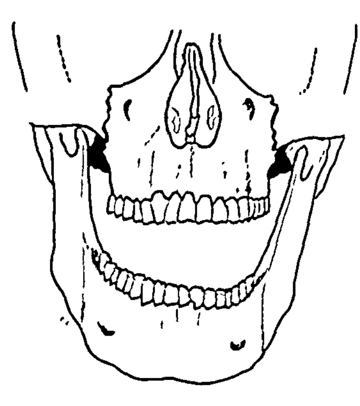


Fig. 2-B

Fig. 1: Normal right lateral movement is shown. The left condyle moves forward and the right moves backward. In left lateral movement, the reverse takes place.

Fig. 2-A: It is assumed here that the left condyle is fixed in its socket. On mouth opening, the right condyle moves anteriorly, given its full range of motion, and the jaw shifts to the left.

Fig. 2-B: Left lateral motion is greater than right, since the left condyle, being more or less fixed, cannot advance. In fixation of the left condyle, the jaw shifts to the left on mouth opening and left lateral motion is greater than right.

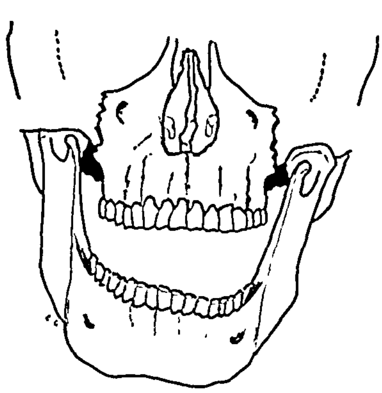


Fig. 3-A

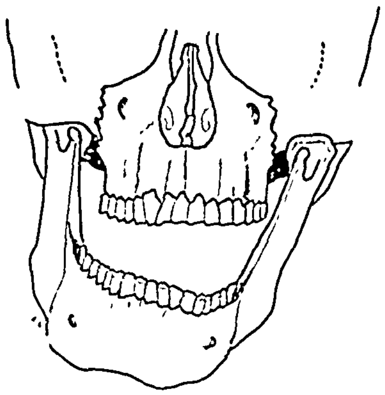


Fig. 3-B

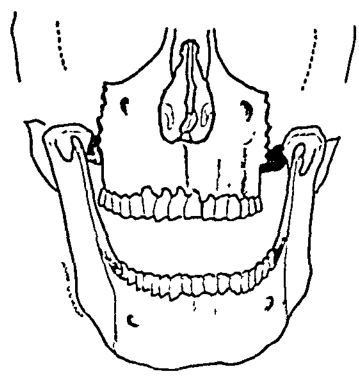


Fig. 3-C

Fig. 3-A: This situation is the reverse of Fig. 2-B. The left condyle is placed anteriorly and cannot be reduced because of meniscal block. The chin goes to the right on mouth opening, because the left condyle is ahead of the right.

Fig. 3-B: Right lateral movement is greater than left, because the left condyle is ahead of the right.

Fig. 3-C: Left lateral motion is less than right, because the left condyle cannot retreat into its socket.

3-C), and on mouth opening the chin shifts to the opposite side (Fig. 3-A). Lateral motion is tested with the mouth partly open.

It is then possible, by analysis of jaw movement, to know which joint is involved and whether it is in or out of its socket. Thus, if the right temporomandibular joint is fixed, the chin shifts to the right in mouth opening and right lateral motion is greater than left. If the right condyle is out of its socket, the chin swings in mouth opening either to the right, if it is fixed in this position, or to the left, if it shows more anterior motion than the left condyle. Right lateral motion is less than left, however, since the right condyle cannot retreat. If the affected joint is very painful, or if the meniscus is not yet "set" or fixed so that lateral motion of the jaw is not carried through a range of movement definite enough for diagnosis, it may not be possible to use these criteria. Diagnosis is then based on the repeated observations of the patient.

There are many reasons why one condyle may move more quickly than its mate, but it is usually an interposed meniscus that stops condylar advance or retreat. Incongruence of the joint surfaces follows joint inflammation more frequently than it does meniscal interposition. Anatomical abnormalities, such as a shallow fossa or a small anterior tubercle, are secondary factors. The condyle may not be able to leave its socket, first, because of meniscal block, and second, because of shortening and thickening of the capsule

and ligaments. Conversely, the condyle may not be able to return to its socket, either because the capsule has become loose or because it has become shortened and thickened.

The derangement of one joint affects its mate, either by obliquity of movement of the jaw when the normal joint moves through its full range, or by partial fixation of the normal condyle. The latter condition occurs more frequently in the acute phase of the illness, particularly as the result of pain; the former occurs in the chronic phase. After operation, both condyles should and do move more evenly and synchronously near or beneath the articular eminence, without a shift of the chin to one side or the other, unless condylar movement in the operated joint is restrained by bone block, or by residual ligamentous and meniscal block. The fixed joint—and the injured joint may become fixed in a few hours or a few days—may show some motion, which is usually insufficient to bring its condyle forward. Fixation may be greater roentgenographically than clinically.

The trauma which causes loosening or tear of the meniscus may be either intrinsic or extrinsic; extrinsic trauma is either direct or axial. Men are more frequently injured by extrinsic trauma, women by intrinsic trauma. The intrinsic injuries, such as yawning, chewing, talking, the dropping of the jaw in sleep, dental malocclusion, and prolonged mouth opening, as in dental work, do not impress themselves on the mind of the patient as do the grosser, blunter, extrinsic traumata. The onset of disability in intrinsic trauma is

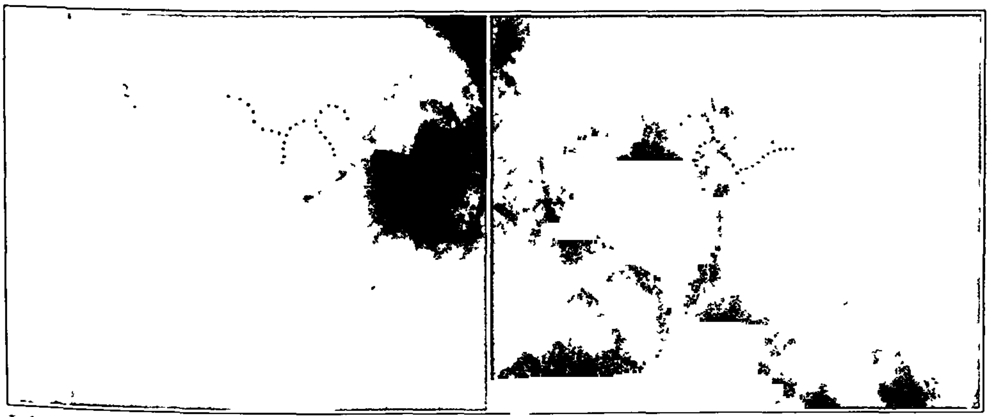


Fig. 4-A

Roentgenograms of the normal temporomandibular joint, taken with the mouth open one-quarter inch (left joint) and three-quarters of an inch (right joint). The condyle goes under the eminence between one-quarter and three-quarters of an inch of opening.

Fig. 4-B

The left joint is shown at one and one-quarter inches and the right joint at one and three-quarters inches of mouth opening. Each condyle is anterior to the eminence.

gradual or sudden, and one characteristic observation is the aggravation or onset of acute disability in the morning, after the jaw has been relaxed during sleep.

A blow to the jaw, at or near the temporomandibular joint, or an axial blow to the chin whose force is sent to the opposite condyle, causes sudden contraction of the pterygoideus externus; the pull of this muscle forces the meniscus forward and medially. The intrinsic traumata keep the condyle in a *forward position*. The temporomandibular joint becomes painful and the adjacent area may be swollen. An annoying click may be heard or felt as the mouth is opened or closed. In the acute stage, the patient cannot open his mouth freely or painlessly, and finds it hard to chew solid food. Condylar motion is usually restricted and the chin shifts to the abnormal side, because the normal joint moves faster than the abnormal joint. If the condyle has been dislodged from its socket, the chin may go to the normal side, since it is placed ahead of its mate. In the latter event the mouth can be closed, but deviation of the chin persists.

As the acute stage subsides, all symptoms and signs lessen. Clicking is not necessarily present. The ability to open the mouth fully may return and the temporomandibular joints may become functionally useful, but permanent inequality and asynchrony of motion may remain. Apparently, enough of the meniscal cartilage is eroded to allow useful function, or it may be placed in such a position medially that it is by-passed by the condyle.

No clinical attempt has been made to dissociate the two movements of the joint,—the *hinge* movement, which takes place in the joint formed by the condyle and the meniscus, and the *gliding* movement in the joint, between the meniscus and the fossa. As a result of acute injury, both actions may be disturbed and the two-jointed temporomandibular joint may behave as a single joint. It is important to determine the integrity of the joint as a whole.

Most patients are treated by rest, heat, and the chewing of soft food. The clicking joint is sometimes treated by the injection of sylnasol, an irritating solution of the sodium salts of certain of the fatty acids of psyllium-seed oil. In the presence of a persistently painful joint, with or without locking, limited mouth opening, and the inability to chew solid food, operation is indicated. The irreducible, anteriorly placed condyle should be replaced.

This study is based upon the clinical examination of the temporomandibular joints of 105 patients; fifty-five were normal and fifty were abnormal. Roentgenographic examinations were made in many cases.

Meniscal disability has been separated categorically into several groups. These need not be distinct, for one group may merge with the other.

THE CLICKING JOINT

The clicking joint is the simplest form of internal derangement. The meniscus is loose or torn, but it does not block condylar motion. Its interposition, however, causes transient or permanent asynchrony of condylar movement. The derangement, especially when it has been produced by intrinsic trauma, occurs preponderantly in women, especially young women. It usually causes slight or no trouble, but in some patients more serious symptoms eventually develop, and these patients may need meniscectomy. The joint may lock temporarily, with the mouth open or closed.

The discontinuance of clicking means one of several things: reposition of the condyle; wearing away of the meniscus; fixation in an abnormal position, as after manipulation; injection of an irritating substance; or operative resection of the meniscus. Manipulation of the jaw intentionally, as under anaesthesia, or unintentionally, as in dental work requiring prolonged mouth opening, may improve the joint whose motions are restricted or it may cause further restriction. It should always be done gently.

Three main forms of clicking joint are described,—the usual anterior form, the unusual lateral form, and the painful anterior form with transient locking.

The Usual Anterior-Motion Form of Clicking Joint

CASE 1: A woman of thirty-five, who was first examined on February 23, 1940, had heard clicking of her left temporomandibular joint for the past year. The click was not constant; it was worse in rainy weather; and it was not caused by trauma or by chewing hard foods. Both condyles had good anterior excursion, especially the left condyle, and the lateral movement of the jaws was good. The patient opened her mouth one and one-quarter inches, with slight shift of the chin to the right. Roentgenograms, taken on February 29, confirmed the anterior excursion of the condyles, but it was not possible to tell which was more anterior. Injections of sylnasol were advised, but the patient refused to have them.

On March 6, 1943, she had no pain in the left temporomandibular joint, but there was occasional clicking. She opened her mouth one and three-eighths inches, but the chin deviated to the right because of greater movement of the left anterior condyle. The left condyle was more prominent. In mouth closing, the right condyle entered its socket first, and, when the left condyle retreated into its socket, the deviation of the chin was corrected. The more quickly advancing left condyle was placed in a position ahead of the right one, and the right condyle could therefore enter its socket first.

This case is illustrative of mild permanent asynchrony of condylar movement in the clicking jaw caused by meniscal interposition.

Clicking Joint Relieved by Injection of an Irritating Solution

CASE 2: A male patient was seen on March 3, 1944. He had had constant, annoying snapping or thudding of his right temporomandibular joint for a year, without known injury. Each day the joint snapped hundreds of times, and sometimes the patient himself would cause it to snap by shifting his jaw to the left. The joint felt worse each morning on arising, although it did not snap more. He had discomfort of the ear. The joint occasionally locked and for a week, six months before examination, he was afraid to open and close his mouth, especially in the morning, for fear of causing the joint to lock. He had formerly slept with his head on his right arm, but abandoned this way of sleeping because it pushed his jaw to the left and, he believed, aggravated the tendency to transient locking.

He opened his mouth one and five-eighths inches. The chin sometimes shifted to the right on partial opening of the mouth, and then to the left on full mouth opening. A thud was heard in the right joint as he opened his mouth from one-half inch to three-quarters of an inch. With his mouth closed, the thud was heard as he shifted his jaw to the left, but not to the right. Lateral motion was somewhat greater to the right than to the left. The joint was not tender.

On March 14, one cubic centimeter of two per cent. procaine was injected into the joint, just behind the condyle, with the mouth open. This had no effect. On March 15, 0.2 cubic centimeter of sylnasol was injected, by similar technique, into the joint. There was no local reaction. On March 20, the patient stated that the snapping had diminished greatly. He felt much better, enjoyed his meals, and was not troubled by the jaw. Objectively, slight clicking occurred with every third or fourth opening of the mouth, and the joint moved more smoothly. He still could snap the joint voluntarily. On April 26, the jaw did not snap and he could open his mouth one and three-quarters inches. He had no complaints.

The Lateral-Motion Form of Clicking Joint

CASE 3: A man, forty-nine years old, whose jaws were examined on July 2, 1940, was being treated for aseptic necrosis of the hips resulting from caisson disease. The jaw findings were incidental but interesting, illustrating condylar asynchrony by lateral movement rather than by anterior movement. The patient had occasional pain in the joint of each jaw on chewing hard food. He had noted catching of the right temporomandibular joint as he opened his mouth suddenly and swung it to the right. This happened about once a month, and he reduced the dislocation easily by pushing his jaw to the left. The catching had been observed for four or five years and was correlated with no known trauma. Sometimes he had a peculiar feeling in the right ear.

On opening the mouth, both condyles moved anteriorly with a thud, and they retreated with a thud on mouth closing. The chin did not shift on anterior movement. The patient could move his jaws laterally with unusual facility. On right lateral motion, with the mouth partly open, the left condyle became prominent anteriorly and medially and the right condyle was placed posteriorly and laterally. The reverse took place on left lateral movement. Each condyle, especially the right, entered its socket with a thud.

Roentgenograms of the laterally shifted jaw, taken on July 15, showed the anterior position of the condyle on the side away from the direction of movement. The condyle was distorted and broadened.

This is an unusual form of disability, since the important condylar motion is anterior and not lateral. It is a dissociated form, in which anterior movement is free and lateral motion gives the symptomatic clicking as the condyle passes the interposed meniscus.

The Painful Clicking Joint with Transient Locking

CASE 4: A woman, thirty-four years old, was examined on September 14, 1943, and stated that she had had pain in the left temporomandibular joint for two months. This apparently followed prolonged mouth opening during a dental treatment, three months before. No other trauma was known. Intermittent pain began two days after the third dental treatment. Lockings developed two weeks before examination.

The jaw caught every few minutes as the patient opened her mouth. She moved the jaw from side to side or back and forth to unlock it. The joint clicked loudly each time it went out of place. Even talking locked the joint. As the joint caught, she had very sharp pain, which did not radiate to the ear. She had been unable to eat solid food for a week. The condition was worse in the morning, between five and eight o'clock. She had tied her jaws together at night to prevent this morning pain, and used a tube to sip liquid foods. She had also applied ice bags to relieve the swelling of the part.

The left temporomandibular joint was very tender. The patient could open her mouth very slowly to about one inch and often only to one-half inch; the left condyle became prominent and the jaw shifted a little to the right. The left joint cracked roughly and the right one did so to a lesser degree. At frequent intervals, the left joint stuck on mouth opening, at which time she had a good deal of pain. She then moved the jaw from side to side, the joint unlocked, and the pain was relieved. During this manoeuvre, the left joint cracked a good deal. The facial muscles were not atrophic.

No roentgenograms were taken. Meniscectomy was advised, but was not done. On October 28, the jaw was still very painful, but there was less swelling.

CASE 5: A woman, forty-nine years old, was examined on March 4, 1943, because of a sharp pain which had been present in the left temporomandibular joint for five months. There was no known trauma. She found it hard to open the mouth and to chew hard foods. She heard knocking and cracking noises within the joint as she moved it; these had increased recently. She had noticed deviation of the chin to the left on mouth opening. She had worn dentures for from ten to fifteen years. She had rheumatism of the fingers and toes.

The mouth opened one and one-eighth inches, with a marked shift of the jaw to the left. The right condyle showed a good range of motion; motion was limited on the left. Painful thudding noises were felt and heard in the left joint as it moved. On closing the mouth, jaw obliquity was corrected and the chin went to the mid-position. The left joint was tender.

Physical therapy was advised and the patient took a few treatments, but she was not better on August 31. The left joint then showed transient locking as she talked. She was able to unlock the joint and to close her mouth. Operative removal of the meniscus was advised, but was not done.

It may be difficult at times to rule out primary arthritis, as in this case, but it should be remembered that rheumatoid arthritis is usually polyarticular, and that the temporomandibular joint is only one of many joints involved.

INTERPOSITION OF MENISCUS

The interposed meniscus can stop the condyle from leaving its socket. Three groups are described: (1) the untreated joint which is cured spontaneously; (2) the untreated joint in which secondary arthritic changes develop as a result of long fixation; and (3) the fixed joint which is released by operation.

1. *The Untreated Joint which Recovers Spontaneously*

The fixed joint may develop within a few hours or a few days after trauma. This is shown by the following cases:

CASE 6: A woman of thirty-seven, who was seen on March 11, 1943, had been struck on the right jaw two days before. Since then, the jaw had been swollen and painful. She could not chew, bite, or yawn. The right jaw was swollen near its angle; the swelling extended cephalad to the condyle and medially over the face. The right temporomandibular joint was very tender. The mouth opening was only three-quarters of an inch and it was accompanied by cracking of the joint and shifting of the chin a little to the right. Right condylar motion seemed absent, but there was a fair range of left condylar motion.

The roentgenograms were negative for fracture. The right condyle remained in its fossa when the mouth was opened.

CASE 7: A woman of twenty-eight was examined on May 13, 1940, because of pain which had persisted in the left temporomandibular joint since the winter of 1937. She stated that her father frequently struck her on the left side of the face when she was a child, and even up to the age of sixteen. At eighteen, she was hit on the right side of the chin by a drunken companion. She was dazed for a short time, but did not have pain in either joint. She was in an automobile accident in 1933, which dazed her for half an hour. She thought the present disability occurred suddenly, as she was yawning. She opened

her mouth well, but could not close it fully; the joint locked in the partially open position. The mouth opened one-quarter of an inch, and forced opening was painful. This condition persisted for three days, and she could take only fluids and cereals. Thereafter, the joint snapped loudly when she opened and closed her mouth. Lockings occurred at least once a day for about six months. Sometimes the locking lasted half a day, and the joint unlocked in the relaxation of sleep. By locking, the patient meant the inability to open her mouth, although she could close it. She had pain in the left joint as she opened her mouth, but the pain did not radiate to the ear. The chin shifted to the left with each mouth opening.

The condition had improved by the next spring and the snapping lessened, giving way to a finer cracking sound. The patient was then well until six or eight weeks before examination, when she again noted cracking of the left temporomandibular joint each time the mouth was opened. She had dull pain on closing the mouth. She could not chew food, but swallowed it whole. The pain was located in front of the ear and radiated to the temple and to the ear canal. She was not deaf nor was salivation increased. There was now no snapping and no locking. Mouth opening and closing were free, and the chin did not deviate. The pain reached its maximum for a period of three or four days. a week before the examination, but at the time of the visit she had no pain except on left lateral movement of the jaw. This pain was slight and radiated to the ear. She could now chew well.

She opened her mouth one and seven-eighths inches, with no deviation of the chin, but as she closed her mouth the chin went to the left and then to the mid-line. After the more prominent right condyle had entered its socket with a thud, the slower left condyle entered its socket without sound. The temporomandibular joints did not crepitate. The left side of the face was somewhat atrophic. The angle of the jaw was 125 degrees. Each joint showed good lateral motion. Roentgenograms, taken elsewhere on May 6, indicated good anterior excursion of each condyle. Anterosuperiorly, the left temporomandibular joint seemed wider than the right, and the condyle rested more posteriorly.

It was evident that this patient had a meniscal tear, which blocked the mouth opening, and that with time she had worn away part of the blocking meniscus to allow free function. She was left with a certain residue of disability by incomplete meniscal erosion, however, so that there was decreased left condylar movement and slight asynchrony. This is a good example of a natural cure, which, as in this instance, usually proves to be incomplete. Surgical cure is quicker and more certain.

Case 8: A man, twenty-eight years old, who was examined on February 17, 1942, believed that his left temporomandibular joint had been slipping out of place for three months. He knew of no specific accident to cause his trouble. The jaw clicked painlessly at least three times a day on mouth opening, and he found it hard to chew solid food. Ten days before the examination, he found himself unable to open his mouth more than an inch. The left joint seemed to go out of place, after he ate a crust of bread, but it slipped into place quickly as he closed his mouth. The same thing happened the morning of examination, but this time the joint did not slip into place. He could not now open his mouth well.

The left temporomandibular joint showed some fullness, but it was not tender. The mouth opening was three-quarters of an inch, with slight deviation of the chin to the right. No movement of the condyles could be felt. The right side of the face was full; the left side was flat.

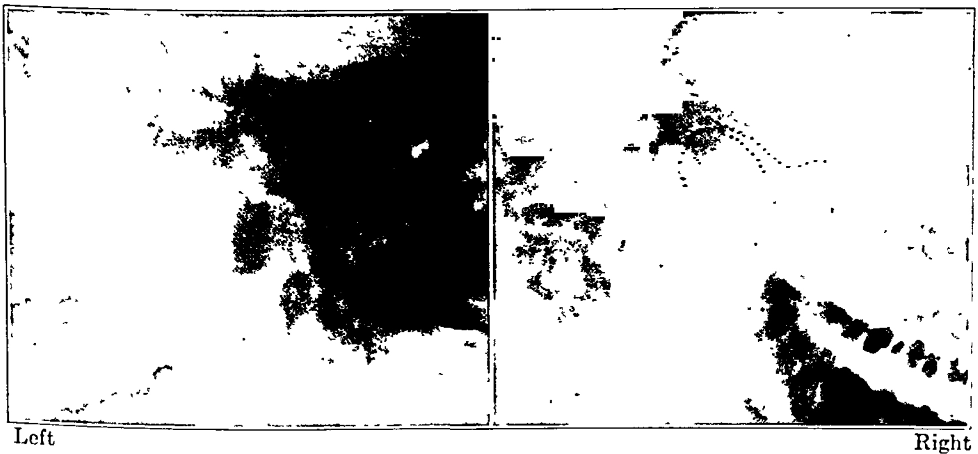


Fig. 5

Case 8. Open-mouth views, taken on February 18, 1942, of both temporomandibular joints. Fixation of the left condyle by meniscal interposition restrained movement of the normal right condyle. The mouth opened three-quarters of an inch. The left condyle did not move at all, but the right one moved to the anterior part of the socket.

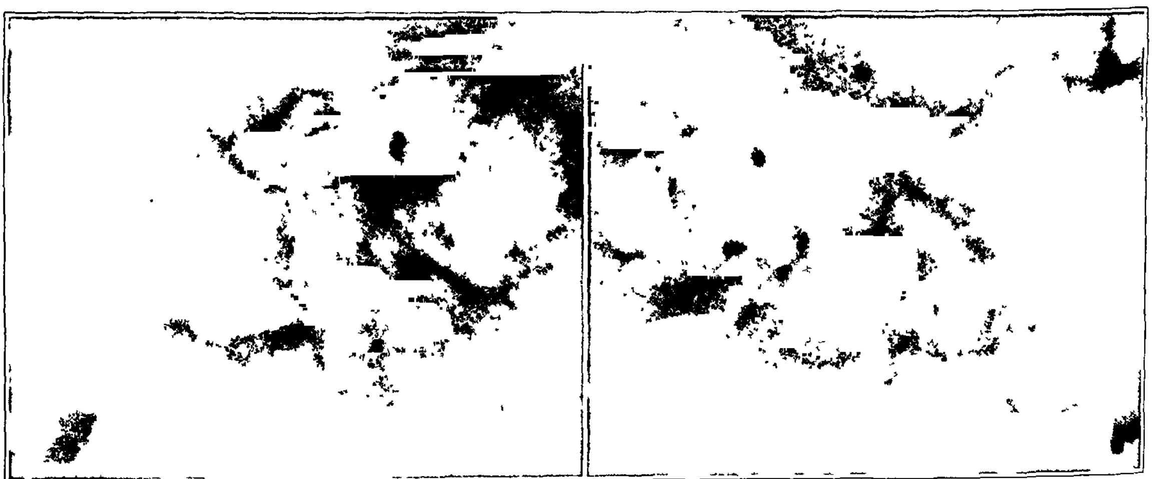
Roentgenograms, taken February 18 with the mouth open (Fig. 5), showed the absence of normal anterior movement of both condyles, which remained in their sockets. In other words, fixation of the left condyle by meniscal interposition restrained the movement of the right condyle, proving that both condyles act as a unit.

Fig. 6-A

Case 10. Photographs taken on April 20, 1940, just before operation. The right temporomandibular joint is fixed in its socket and the chin shifts to the right on mouth opening.

Heat and a soft diet were prescribed. On February 26, he opened his mouth seven-eighths of an inch, and he could open it a little more after the application of heat. He felt tension in the left temporomandibular joint on mouth opening. When seen on April 18, 1943, he had no pain in the left temporomandibular joint except when he opened his mouth for a long time, as in a dental treatment. He opened his mouth one and three-quarters inches, but the chin still shifted to the right. On September 12, 1943, he had no pain and could eat anything. The joint had begun clicking a month before, after nine months of freedom from such clicking. The mouth opened one and three-quarters inches, and the chin shifted at first to the right and then to the mid-line. Again on closing the mouth, the chin went first to the right and then to the mid-line.

A natural cure was anticipated, in view of the short history of disability.



Left Right

Fig. 6-B

Preoperative roentgenograms, taken on April 13, 1940. Roentgenograms of the closed mouth show both condyles in sockets.

Left Right

Fig. 6-C

Open-mouth roentgenograms of the same date. The right condyle is fixed and the left condyle has a little anterior movement.

2. *Fixation of the Untreated Joint*

The untreated temporomandibular joint which is fixed in its socket may show secondary arthritic change. The masseter and temporalis muscles become atrophied, either by the effect of direct trauma or through disuse. Hypertrophy of the masseter gives the effect of a square jaw. It is not necessarily associated with disability of the temporomandibular joint.

Case 9: A man, forty-nine years old, who was examined on April 15, 1940, had been struck on the left jaw some years before by a fist. This caused immediate pain and swelling of the injured part, and three months later he noted clicking of the joint of the left jaw and atrophy of the left side of the face His chin shifted to the left when he opened his mouth. The left temporomandibular joint crepitated on mouth opening and the condyle moved very little The right condyle moved forward quite well beneath the articular eminence. The left masseter was markedly atrophic. The angle of each jaw was 130 degrees

Fig 6-D

These postoperative photographs were taken on June 12, 1940 Mouth opening is one and one-quarter inches and the chin does not shift.

Left Right

Fig. 6-E

Postoperative roentgenograms, taken on June 3, 1940 The open-mouth view shows some forward advance of the right condyle, but less than the left.

Left Right

Fig. 6-F

Closed-mouth view.

Roentgenograms, taken on May 24, showed narrowing of the joint space on the left, with flattening of the condyle. These changes are indicative of secondary arthritis. On mouth opening, the left condyle moved to the articular eminence, while the right condyle was anterior to it. The left condyle showed more motion by roentgenogram than appeared clinically.

3. *Operative Treatment of the Fixed Temporomandibular Joint*

CASE 10: Mrs. F. M., nineteen years old, was first examined on April 12, 1940. She had been struck a hard fist blow on the right jaw, three and one-half months before. She felt as if something went out of place, and at dinner that evening the jaw clicked painlessly each time she opened her mouth. She opened her mouth halfway without difficulty, the jaw clicked, and the mouth could then be opened wide. A month after injury, a dull pain was felt in the jaw; this pain radiated down the neck. She thought the chin at that time deviated to the left on mouth opening. The jaw was manipulated under anaesthesia by another physician about that time, and was strapped for a week. The click disappeared after manipulation, but she then became unable to open her mouth. Apparently, after manipulation, the loose meniscus became fixed, so that excursion of the anterior condyle was blocked. She noted overlapping of the lower teeth by the upper teeth. She could not chew hard foods or large boli of food. Because of a carious left molar tooth, she chewed her food mainly on the right side, and the left temporomandibular joint became more painful than the right.

The chin was questionably deviated to the right on mouth opening. Right condylar motion could not be felt, but there was excursion of the left condyle, which was limited by stiffness of the right temporomandibular joint. The mouth opening was three-quarters of an inch; the right jaw grated (Fig. 6-A). A left upper molar tooth was carious, and this was removed.

Roentgenograms taken on April 13, 1940, (Figs. 6-B and 6-C) showed no excursion of the right condyle with the mouth open, and only slight anterior excursion of the left condyle. The right joint space was cloudy, a finding which had been absent in roentgenograms taken on December 11, 1939.

The right joint became "frozen" by meniscal interposition after the manipulation, and later by ligamentous contracture. The fixation of the right joint prevented the full excursion of the left condyle.

On April 20, under local novocaine infiltration anaesthesia, the right temporomandibular joint was approached by a modified Burdick incision. The ear part of the incision overlay the pinna and the vertical arm crossed the temporomandibular joint. This made almost all of the incision lie in the hairline. The zygoma was defined, and then the temporomandibular joint. The striking finding was the thickening of the capsular and ligamentous tissues, which bound the joint firmly. These tissues were excised, as was a loose meniscus. After this had been done, the mouth could be opened wide and the condyle rode normally beneath the articular eminence. The wound was closed, and a Barton bandage was applied. A small venous ooze from the ear was noted, and the ear was packed with sterile cotton.

The postoperative course of this patient was uneventful; the only complicating factor was a tear through the membranous part of the right external auditory meatus, which caused slight difficulty in hearing and was responsible for buzzing and ringing. The tear followed the use of a sharp-pointed automatic retractor. Twice, a spicule of bone was extruded through this ear opening. The ear had healed by June 10, the canal was patent, the tear healed, and hearing was normal. The patient chewed paraffin and gum and the return of motion was rapid (Fig. 6-D).

Roentgenograms made on June 3, 1940, (Figs. 6-E and 6-F) showed slight motion of the right condyle and fair motion of the left, with the condyle almost riding the eminence.

The patient's last visit was on January 10, 1941. At that time she could eat all hard foods. She had some pain in the region of the right temporomandibular joint in rainy weather. The mouth opening was one and three-eighths inches. The condyles could not be felt. Slight hypaesthesia was still present in the right temporal area. She could move the jaw to the right more than to the left, both with the mouth open and closed.

CASE 11: Mrs. E. O'C., a woman of forty-six, was first examined on January 14, 1944. She had been struck a very hard blow by a closet door a year and a half before, in the region of the right temporomandibular joint. The joint area remained sore for at least six weeks. Clicking began about two or three months after the injury, especially when she was eating. Locking occurred every few weeks, with the mouth partly open. Since the accident, she believed that the right lower teeth were wearing away "at a slant" because of an unequal bite. A right upper molar had been extracted in the spring of 1943. Other right molar teeth, both upper and lower, had been extracted twenty-five years before. With a little care, she had been able to eat everything, and she had been able to open her mouth fully.

She was chewing candy a few days before Thanksgiving of 1943, when the right temporomandibular joint clicked two or three times, and an hour later she could not open her mouth more than three-quarters of an inch. A meniscal derangement was diagnosed by her physician. An attempt to open her mouth had been made four weeks before, under intravenous anaesthesia, but this made the disability worse. After manipulation, she could open her mouth only one-half inch. For the two weeks before

examination, she complained of soreness in the right joint, with pain referred to the ear. She could eat only soft or mashed foods.

On mouth opening, the interdental distance was three-eighths of an inch. Tenderness was present over the right temporomandibular joint. She could move her jaw to the right much better than to the left. The chin shifted to the right on mouth opening, and this shift was also seen with the mouth closed (Fig. 7-A). Roentgenograms confirmed the clinical diagnosis that the right condyle was "frozen" in its socket (Figs. 7-B and 7-C).

On January 21, 1944, the right joint was explored under local infiltration anaesthesia with novocaine. The capsule may have been slightly thickened. The meniscus was torn in two, and the anterior part had been displaced medially. When this part of the meniscus had been removed, she opened her mouth well, with no obliquity and with equal lateral motion.

The postoperative course was good. There was swelling and ecchymosis of the loose areolar tissues beneath the right eye ("black eye"), and a subconjunctival hemorrhage in the right eye. This subsided quickly. The right side of the forehead did not wrinkle, presumably because of retractor pressure.

The patient received physical therapy. Her progress was slow, possibly because the most antero-medial part of the meniscus or ligament was not resected. Mouth opening on February 18, 1944, was three-quarters of an inch, with a slight shift of the chin to the right. On March 22, it was seven-eighths of an inch, with the chin shifting slightly to the right. Wrinkling of the right side of the forehead was returning. On April 5, mouth opening was one inch, but the involved joint was still painful at times. On June 21, she could open her mouth one and one-quarter inches, and there was a slight shift of the chin to the right. Wrinkling of the right side of the forehead was now present. Several of the lower left teeth had been removed during the previous month, and she had to chew on her right side. She rightly attributed the increased motion of the joint to this fact. Proper dentures were made after operation to give proper chewing and hence better joint motion. The involved joint was now not painful, but it was a little stiff in the morning. Roentgenograms (Figs. 7-E and 7-F), made on January 5, 1945, showed an excellent range of motion of both condyles.

On microscopic study, the meniscus showed degeneration and, at one point, a defect with some evidence of repair. A tiny fragment of parotid-gland tissue was seen in the tissues studied; it was obtained from a part of the parotid gland which enters the posterior part of the joint.

TRUE DISLOCATION

It has been stated that the temporomandibular joint is the only joint which dislocates normally. The condyle leaves its socket and can return to it at the will of the patient. In this sense, it corresponds with the so-called habitual or relaxed dislocation of other joints, but in other joints the movement is in excess of normal. When the condyle cannot return to its socket by meniscal interposition, an irreducible dislocation exists. This is a true dislocation, in contrast to the normal or false dislocation of the condyle.

CASE 12: A woman of thirty-four fell down two flights of steps on February 21, 1940, injuring her head, left leg, and right shoulder. Her important complaints on April 30 concerned the right supraclavicular region, which was painful and swollen, and the right shoulder. She had noted no trouble with the jaws before the accident.

The examination showed a dislocation of the sternal end of the right clavicle, bilateral very large cervical ribs, sprain of the back and of the cervical spine, and strain of the right shoulder. She opened her mouth in a jerky manner; both condyles were more anterior than usual and the chin deviated to the right. Each condyle was prominent and a depression was felt posterior to it. In mouth closing, each condyle retreated into its socket with a thump, as if overcoming a bony obstacle. This was followed by a click in each jaw, which was louder and more painful on the left. The pain was referred to the ear. Tenderness was present on the left side in the space between the condyle and the mastoid process. The angle of the jaws was 125 degrees, and the patient could open her mouth slowly to one and three-quarters inches.

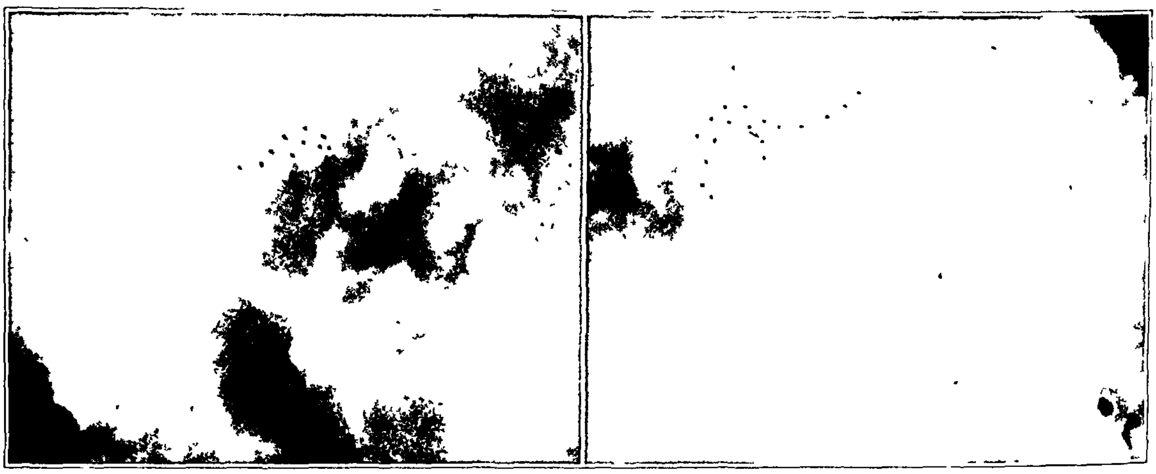
Roentgenograms made on May 6 showed that the left condyle did not enter its socket in the closed-mouth position and that it was irreducibly dislocated anteriorly by meniscal block. The neck showed marked limitation of lateral motion, but roentgenograms of this region were negative. No treatment was given.

The injury of the temporomandibular joints is part of a more diffuse injury to the head and neck. This association is so common that the function of these joints is tested in any case of severe blunt trauma to the head and neck.

CASE 13: Mrs. K. R. V., a woman of twenty-seven, was first examined on November 17, 1939. On April 15, 1937, she had struck the left side of her head against a bus seat, as the bus stopped suddenly.

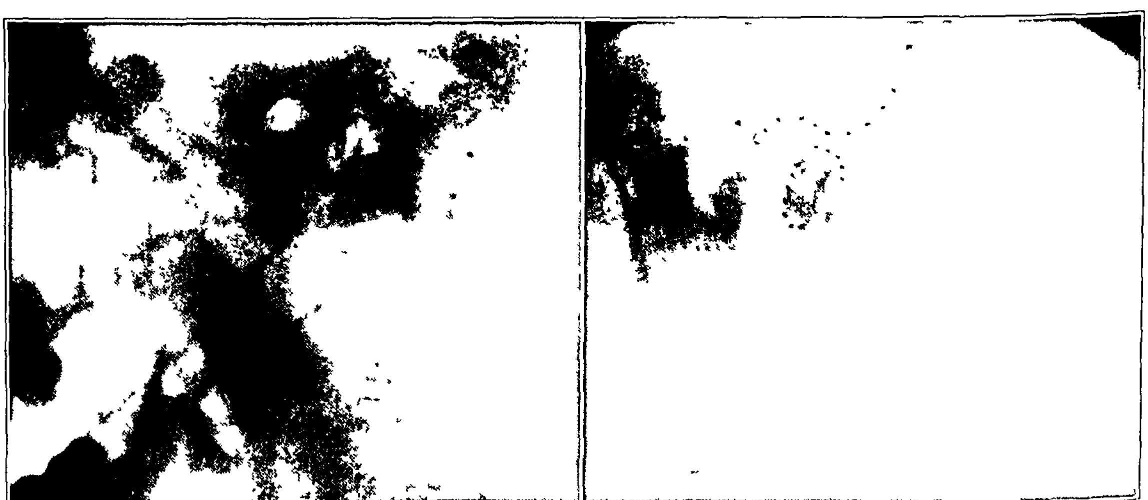
FIG. 7-A

Case 11. Photographs taken on January 20, 1944. The chin shifts to the right on mouth opening, because the left condyle moves more easily and more anteriorly. Right lateral movement is better than left lateral motion. A clinical diagnosis of fixation of the right condyle in its socket was made before roentgenograms were taken.



Left Right

FIG. 7-B



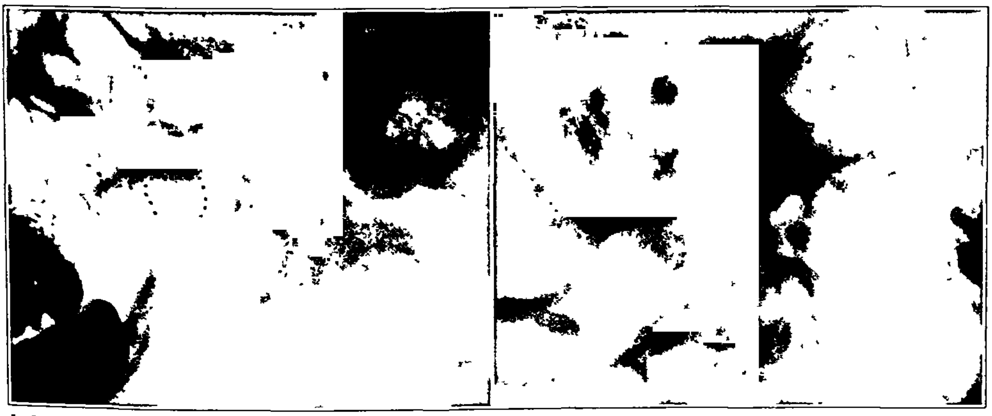
Left Right

FIG. 7-C

Closed and open-mouth roentgenograms, taken on January 19, 1944, two days before operation. Both condyles rest in socket in the closed-mouth view; in the open-mouth view they move to the anterior part of the joint, but do not go under the eminence. The movement of the normal left condyle is restrained by the blocked right condyle. Mouth opening does not exceed three-eighths of an inch.

Fig. 7-D

Postoperative photographs, taken on January 30, 1945. Patient had no trouble with the jaw joint after operation. Mouth opening was one and five-eighths inches, and both condyles moved well. The right condyle grated a little on motion. The chin did not deviate on opening the mouth, and lateral motions were equal.



Left Right

Fig. 7-E

Left Right

Fig 7-F

Roentgenograms of January 5, 1945, closed and open-mouth views, confirmed the excellent anterior range of both condyles. The right condyle was under the eminence and the left condyle was anterior to it.

FIG. 8-A

Preoperative photographs, taken on November 4, 1944. J. C., a woman, twenty-four years old, had had her head snapped backward on September 5, 1944, as a street car hit her automobile. She was placed in head-and-neck traction and a Calot jacket was applied on September 29, 1944. During the period of traction, she complained of pain in the right temporomandibular joint. The pain and inability to open the mouth increased rapidly, so that a meniscectomy was done on November 6. The capsule was thickened and the meniscus was displaced anteromedially. Not all of the meniscus could be removed. She had transient paralysis of the right side of the forehead, with absence of wrinkling. Photograph shows the range of mouth opening and the lateral movements allowed. The roentgenograms proved that both condyles did not leave their sockets on mouth opening; fixation of the right condyle restricted the movement of the left condyle. This case illustrates the fact that injury to the head and neck is not infrequently associated with injury of the temporomandibular joint.

FIG. 8-B

Postoperative photographs, taken on February 23, 1945. On March 9, the patient could open her mouth one and one-eighth inches. There was a little deviation of the chin to the right, by greater forward motion of the left condyle. Right lateral motion exceeded that on the left, but both were restricted. The right condyle was slightly tender.

The injured half of her face quickly became swollen. She was told that the left jaw was dislocated, and this dislocation was apparently reduced four days after the injury. Dislocation recurred, and attempts at reduction were made on four different occasions over a period of several months, without complete success. Before the first reduction, she opened her mouth with discomfort and could not chew solid foods.

The patient stated that the jaw still dislocated many times a day on opening the mouth wide. She had a dull pain in the left temporomandibular joint after chewing, and she could not chew hard foods. When chewing on the right side, there was an annoying, painful clicking of the left temporomandibular joint. She could close her mouth, but had noted altered occlusion of her teeth, with a shift of the mandible to the right. The swelling of the angle of the affected jaw still persisted. More recently, she complained of a deep clicking in the left ear.

The lower jaw did show a lateral shift to the right, with malocclusion of the teeth; the upper teeth overlapped the lower set. The left half of the face seemed broader and flatter than the right, and the left half of the mouth was wider than the right, especially on mouth opening. The left mandibular condyle was tender and prominent, and slipped forward with a click. Mouth opening increased the

mandibular deviation. On mouth closing, the condyle seemed to slip into place. The patient was able to thrust the jaw forward and also backward. In the dislocated position, the angle of the jaw was placed more posteriorly than normal. The temporal area was tender, and the molar bone and zygoma were prominent. Roentgenograms showed that, in the closed position of the mouth, the left condyle was at the anterior part of the socket and, on mouth opening, the condyle moved forward normally (Fig. 11-A).

On January 16, 1940, under local novocaine infiltration anaesthesia, the temporomandibular joint was exposed by the Burdick incision. After the exposure of the zygomatic process, the temporomandibular joint was easily identified. Care was taken to keep within the safe triangle, described by Morris. *The capsule of the joint was thin and loose.* The loose meniscus was removed in several pieces. The articular eminence was small and, even after removal of the meniscus, the jaw seemed to show undue mobility. An anterior block was made, as described by Mayer, and a half-inch piece of zygoma was used as the graft. The eminence was split horizontally and pried down, as in a shelf operation for an inadequate acetabulum,* and a bone graft was inserted into the gap. A plaster helmet was applied after the wound had been closed, and was worn for six weeks.

The operation assured a better articular eminence and provided an anterior buttress, which, it was felt, would be mechanically sufficient after healing to prevent the anterior dislocation of the condyle. The postoperative course was good, except for considerable swelling of the left side of the face, including the eye. The facial nerve was not injured.

Fig. 9-A

Preoperative photographs of M.V., a male, aged twenty-six, taken when he was examined on February 1, 1945. He was struck a fist blow in the region of the right temporomandibular joint, five months before he was first examined. The right joint gave evidence of pain rather than of restriction of motion, since the mouth opening was from one and one-eighth inches to one and one-half inches. Lateral motion was more restricted on the left than on the right, but both were painful.

Fig. 9-B

Operative removal of the meniscus and resection of the thickened capsule were done on February 16, 1945, with local anaesthesia. These postoperative photographs were taken on April 26. The patient had no complaints.

* This method was suggested by A. Schmier, M.D.

At the examination on April 19, 1945, the patient could open her mouth about one and three-eighths inches, but the chin deviated a little to the left, indicating greater motion in the right temporomandibular joint. Both condyles could be palpated readily, but the left moved less than the right. Right lateral motion of the jaw was less than left lateral movement in the open-mouth position. The bite was good, and she could chew hard foods. The left joint crepitated a little on motion. The left side of the face was fuller than the right. Roentgenograms showed normal excursion of the right temporomandibular joint, but the left condyle remained in its socket on mouth opening, partly due to fibrosis and partly because of the bony block with reverse of the mandibular shift and restraint of right lateral movement. The anterior bone block was well developed (Fig. 11-B).

The bone-block operation is not physiological, since it restrains full anterior movement of the condyle. The removal of the meniscus allows the replacement of the condyle in its socket and this is all that is needed. The shelf procedure does not seem worth while.

CASE 14: On February 12, 1912, a man of forty-four fell a distance of twelve feet to the ground from a broken ladder and struck his chin against the ladder as it lay upon the ground. The chin was lacerated

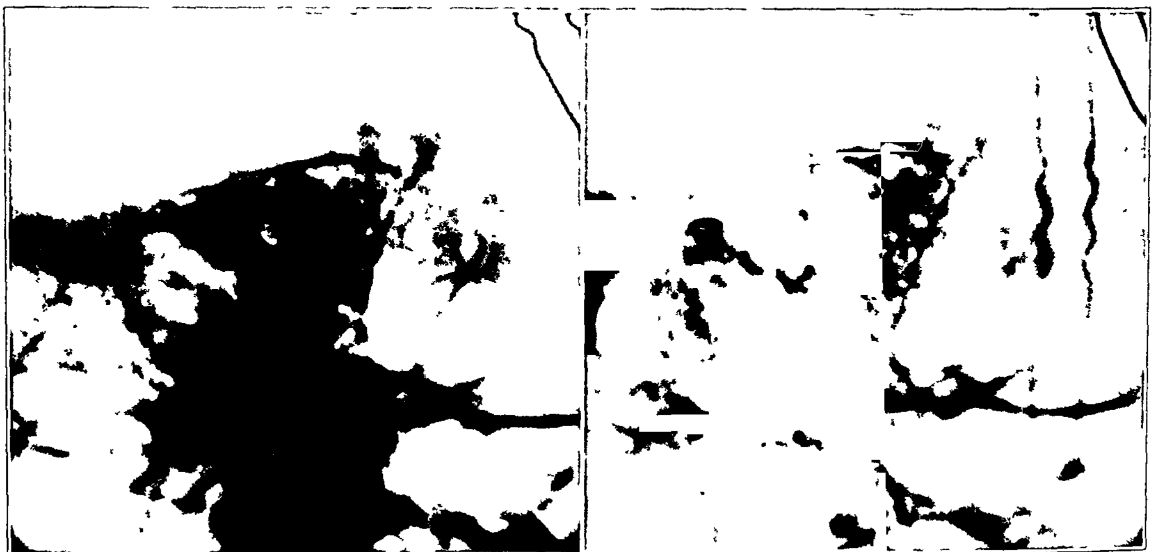
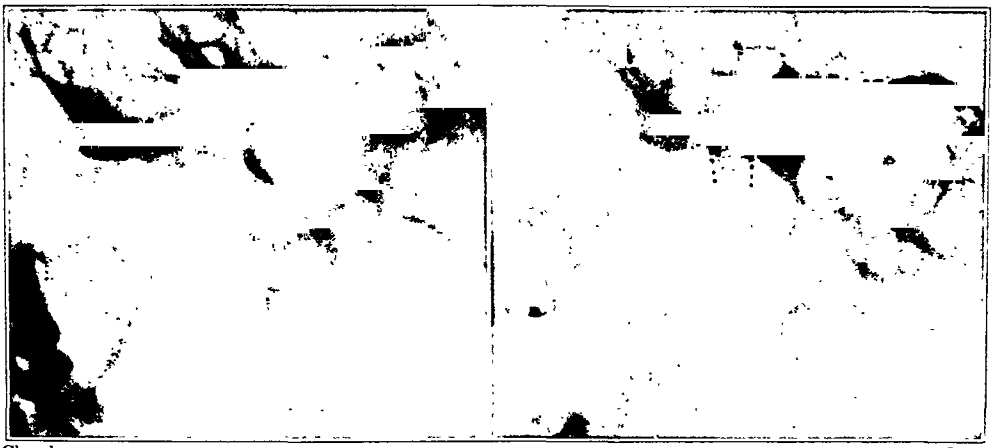


FIG. 10-A

FIG. 10-B

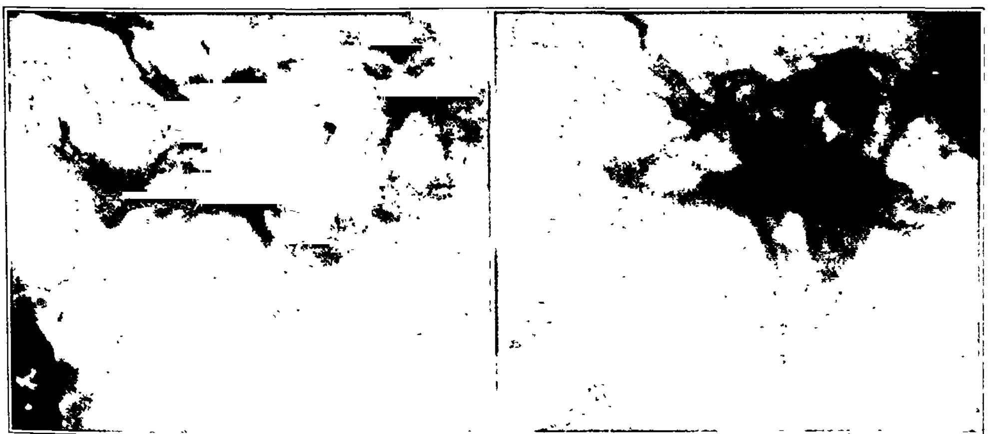
A woman of seventy-five displaced both condyles anterior to the articular eminence while yawning, six days before she was seen in the emergency room of the Hospital for Joint Diseases. This is the only instance in this series in which both condyles were dislocated. The roentgenograms show both condyles to be anterior to the eminence, as in normal full-mouth opening, but the significant difference from the normal is that the condyles could not retreat into their sockets on mouth closing.



Closed Open

FIG. 11-A

Case 13. Roentgenograms of the left temporomandibular joint, closed-mouth view, dated November 17, 1939, show the condyle to be displaced to the anterior part of the socket. With the mouth open, good anterior movement of the condyle is disclosed. The right condyle moves normally.



Closed Open

FIG. 11-B

Closed-mouth view of the left temporomandibular joint, dated April 1, 1940, shows the condyle in its socket. Open-mouth roentgenogram shows that the condyle moves a little, but does not leave its socket because of the bone block.

FIG. 11-C

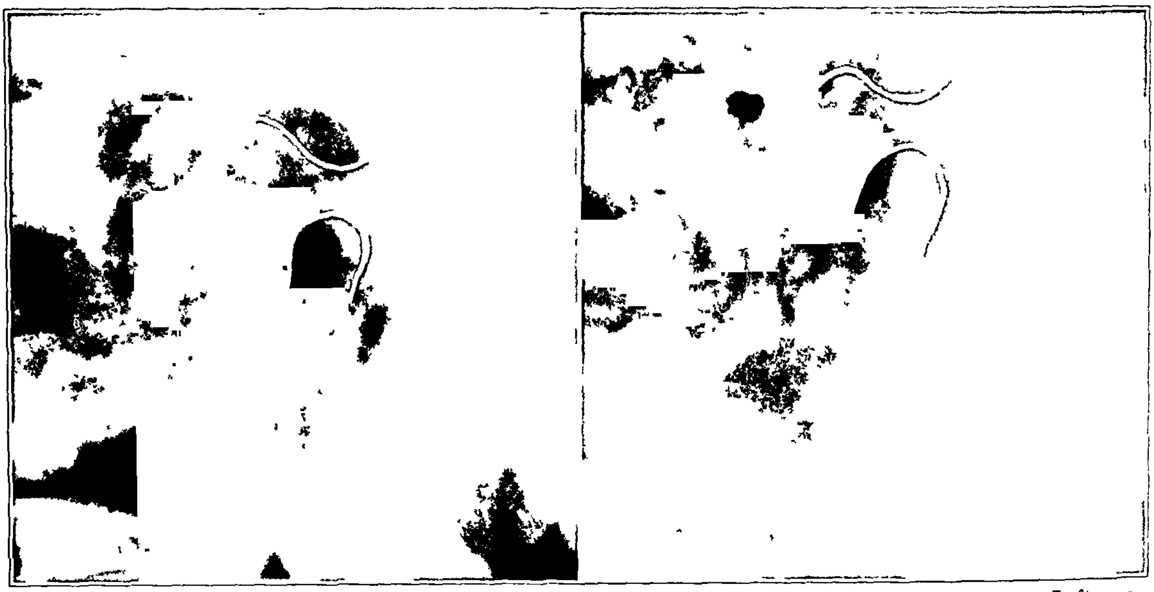
Postoperative photographs taken on April 19, 1945, more than four years after operation. Patient had no complaints. Mouth opening was a little more than one and one-quarter inches; the chin deviated to the left, because left condylar motion was restricted by the bone block. Right lateral motion of the jaw was less than left lateral motion, for the same reason.

and the lower front teeth were lost. The lost teeth were later replaced by a denture. The patient had a cerebral concussion, and bled from the left ear for four days. He was in a hospital for thirty-three days. He stated that, while in the hospital, he could not open his mouth well nor could he chew solid food. He complained of localized, intermittent pain in the left temporomandibular joint, made worse by yawning or by chewing hard food. He had to soften his food by soaking it in water. The left temporomandibular joint clicked at times. He denied previous injury to his jaw.

He was first examined at this Dispensary on December 16, 1942. The left temporomandibular joint

Fig. 12-A

Fig. 12-A: Case 14. This man had an irreducible anterior dislocation of the left condyle. Mouth opening was greatly restricted. The shift of the chin is not well seen in the photographs (taken February 12, 1943).

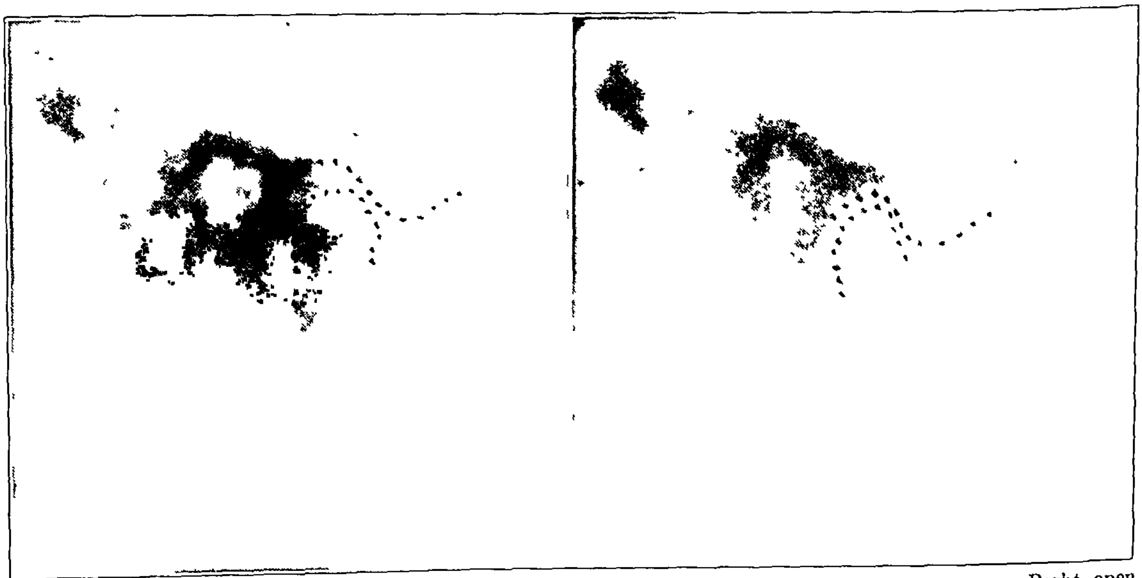


Left, closed

Left, open

Fig. 12-B

Preoperative roentgenograms (made December 16, 1942) of the left temporomandibular joint. In the closed-mouth view, the left condyle is seen in the anterior part of its socket, and it is fixed in this position. (Illustration has been reversed.)



Right, closed

Right, open

Fig. 12-C

The normal right jaw shows restriction of forward excursion of its condyle.

was tender, mouth opening was restricted, and there was a little deviation of the chin to the left. No clicking was heard as he opened and closed his mouth. Left lateral motion of the jaw was limited, but right lateral motion was full and was associated with clicking of the right temporomandibular joint.

Roentgenographic examination of each temporomandibular joint, with the mouth open and closed, disclosed an irreducible, anteriorly placed left condyle (Fig. 12-B). It moved forward a little as the mouth opened. The condyle seemed flatter than normal. The right condyle showed restricted anterior excursion, on mouth opening, by anterior fixation of the left condyle.

Baking and massage were given for the relief of pain. On February 13, 1943, a year after the injury, the anteriorly displaced meniscus was removed under local novocaine infiltration anaesthesia, by a modified Burdick incision. The superficial temporal vessels were ligated. *The ligamentous tissues and capsule of this joint were thickened, scarred, and adherent.* The zygoma showed a small exostosis, inferiorly. After the resection of scarred capsular tissue, the anteriorly displaced condyle was exposed. The meniscus was displaced anteriorly and lay between the condyle and the articular eminence. The fossa was narrow and was filled with scar tissue. The condylar cartilage was grayer and more opaque than normal. The scarred tissues were removed and meniscectomy was done. It was only after division of the shortened anterior ligament that the condyle entered its socket. The range of joint motion was now much greater than before operation. After wound closure, it was noted that the left side of the forehead wrinkled less than the right side. This was attributed to retractor pressure on the branch of the facial nerve supplying the forehead.

The patient's postoperative course was not eventful. Five weeks after operation he could open his mouth one and three-eighths inches, without deviation of the chin, and this range of motion has not increased. He has recovered wrinkling of the entire forehead. He has no pain in the joint and can chew hard foods.

Postoperative roentgenograms showed correction of the dislocation. The left condyle rested within the socket in the closed-mouth position, and advanced just short of the eminence in the open-mouth position; the right condyle advanced a little farther.

On July 14, 1944, the patient stated that the left temporomandibular joint had gradually become stiff so that he could not bite a hard piece of bread. He opened his mouth one and one-eighth inches, with no shift of the chin. Left condylar motion seemed less than right. Each condyle was in its socket and had little anterior excursion.

Fig 12-D

The thickened capsule and ligaments of the left temporomandibular joint, as well as the meniscus, were resected on February 13, 1943. The photograph shows mouth opening on April 17, 1943

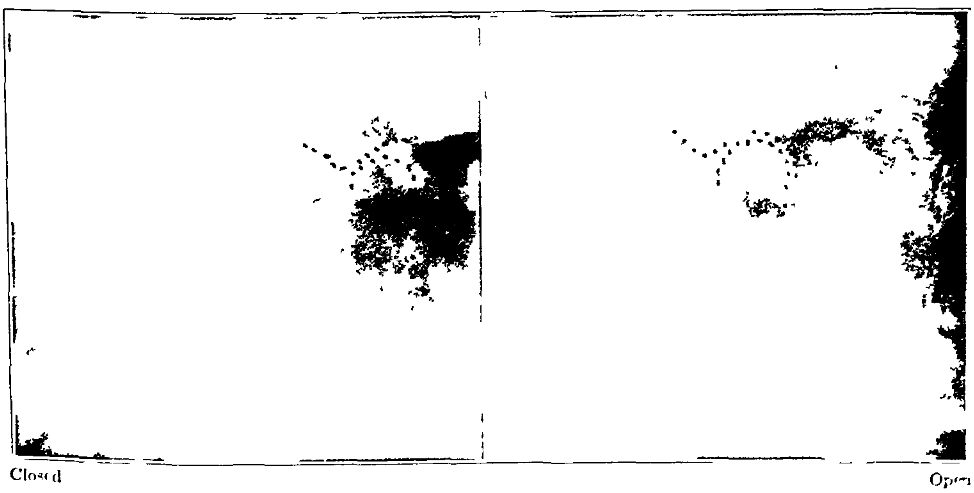
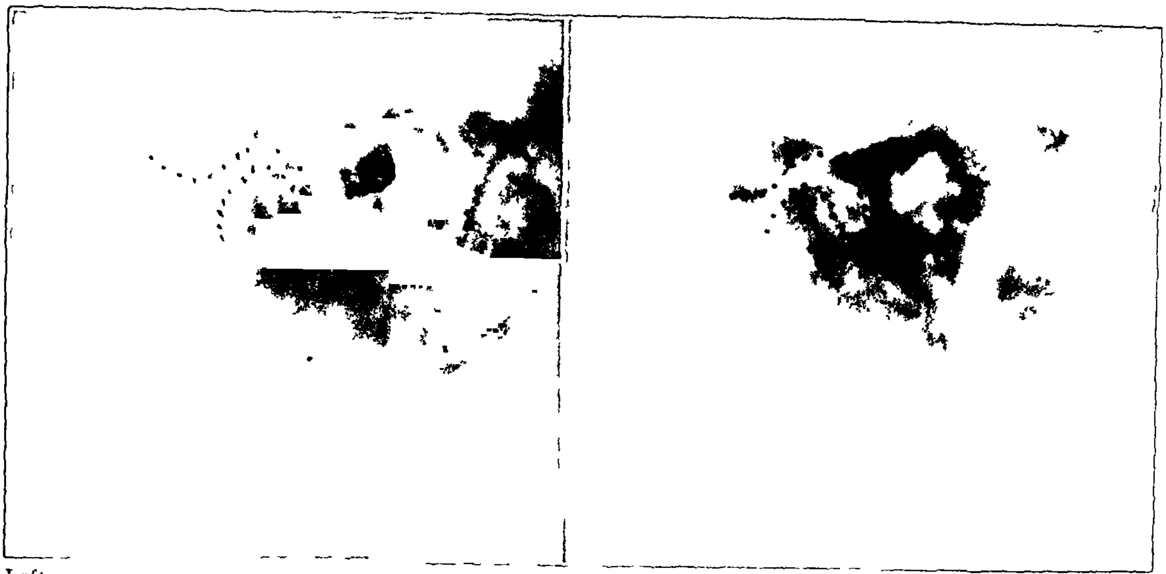


Fig 12-E

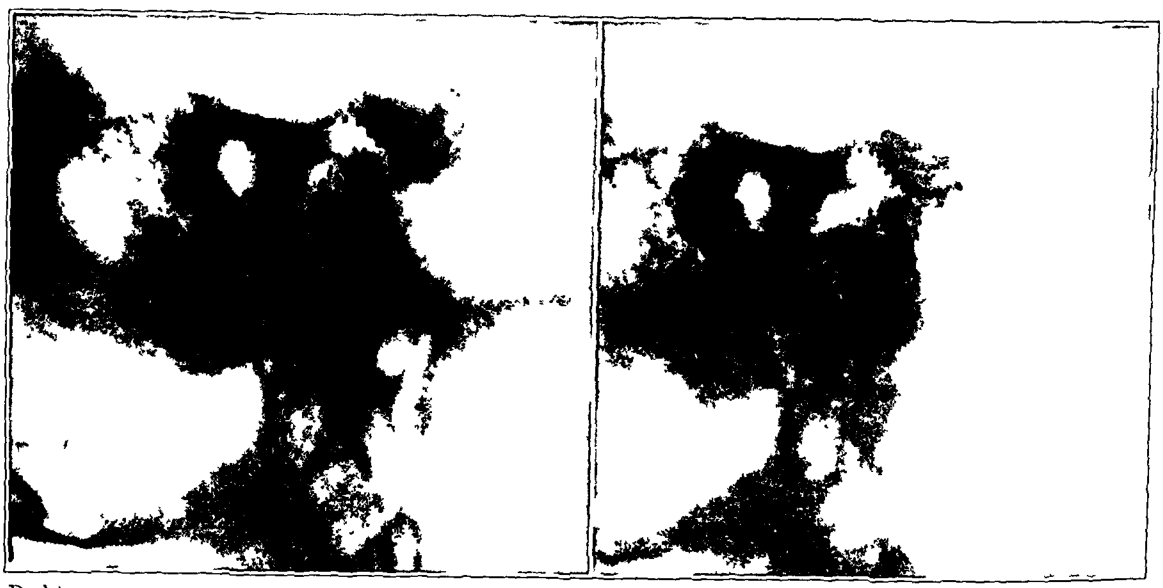
Postoperative roentgenogram of the left temporomandibular joint, taken on September 3, 1943. The condyle is in its socket in the closed-mouth view. The distorted right condyle is seen near it. In the open-mouth view, the condyle moves to the anterior part of the socket.



Left, open

Left, closed

Fig. 12-F



Right, open

Right, closed

Fig. 12-G

Roentgenograms taken on August 15, 1944 The condyles are in the sockets and, on mouth opening, move to the anterior part of the joint.

In one case, it should be noted, the capsule was thin and loose, whereas in the other case it was thickened, scarred, and adherent.

TECHNIQUE OF OPERATION

The operation should be done under local anaesthesia for two reasons: first, to see if normal mouth opening is restored after resection of the blocking meniscus and thickened capsule and ligaments, and second, to have the reassurance that the branches of the facial nerve have not been injured. The drapes are arranged so that the patient's face is examined readily.

A modified Burdick incision is used (Fig. 13). It begins just above the pinna, runs along the zygoma for less than half an inch, and then dips distally for about half an inch. The length of the incision is about one inch to one and one-quarter inches. The tragus and the zygoma are the landmarks, and the incision must stay within the safe area which Morris has stressed. This is bounded posteriorly by the superficial temporal vessels and

the auriculotemporal nerve, which may be sacrificed, and anteriorly by the facial-nerve branches to the forehead and eye. The subcutaneous and fascial tissues are thick and fibrous, and incision is made through them to the zygoma, beneath the posterior part of which the condyle lies. The capsule of the joint is identified, opened, and, if necessary, resected. The meniscus is next identified; the patient opens and closes his mouth for orientation. When the meniscus is loose or torn, it is displaced anteromedially, and this corner of the joint must be properly freed of thickened anterior ligament or blocking meniscus. The internal maxillary artery lies under the neck of the mandible, and runs medially and horizontally. It is usually separated from the mandible by the thickness of the pterygoideus externus. After satisfactory resection of the ligaments and meniscus (a procedure which the operator may find difficult because of oozing of blood, and which he may control by packing the posterior half of the joint), the mouth should open well and the condyle should advance and retreat almost normally. The wound is closed in layers and a Barton bandage is applied. Active movement of the jaw is begun within a week after operation. The chewing of gum or paraffin is encouraged.

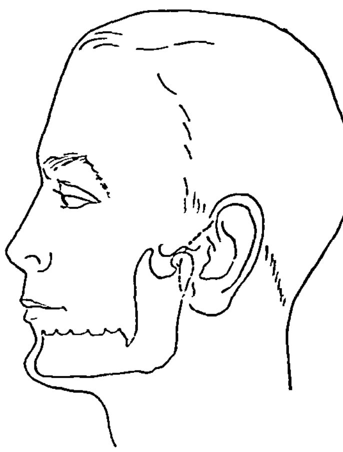


Fig. 13
Modified Burdick incision is shown.

The meniscectomy should be as complete as possible. The limitation of full movement is probably due to the fact that the meniscus, especially its most anterior and medial part, cannot always be fully resected.

CONDYLAR ASYNCHRONISM

A group of unusual cases are described, in which condylar asynchronism is noted.

Fig. 14
Case 15. This woman had a traumatic hemiatrophy of the left side of the face, with asynchrony of condylar movement. Photographs taken June 22, 1940.

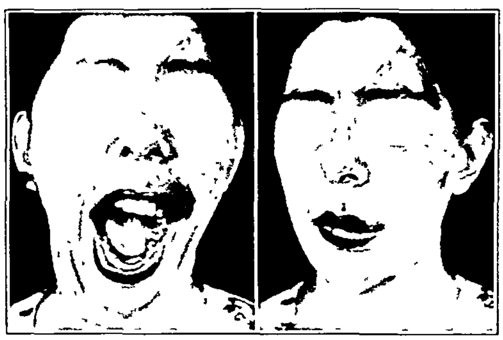


Fig. 15-A
Case 16. This young woman had an extensive naevus flammeus of the left side of her face and forehead, and glaucoma of the left eye. To this syndrome was added left condylar hypertrophy with palatal and dental inclination. The chin was shifted to the right, both with the mouth open and closed, because of the condylar enlargement.

Hemi-Atrophy of the Face and Asynchronism of Condylar Movement

Case 15: A woman, seventy years old, struck the left side of her face against a rock at the age of one year. Since then, there had been atrophy of that side of the face (Fig. 14). This caused no functional disability. The two sides of the face were quite different, and the right half appeared younger than the left. The atrophy included the temporalis muscle (with depression of the temple) and the frontalis muscle. There was no facial-nerve palsy. The left mandibular condyle seemed a little deformed and the

Fig. 15-B

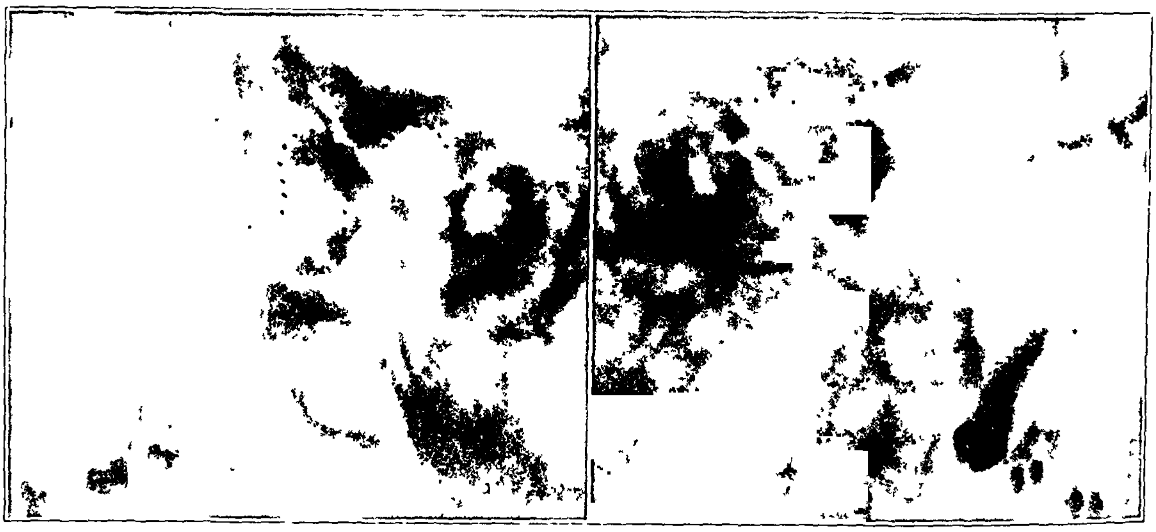


Fig. 15-C

Views of the temporomandibular joints, taken on May 13, 1940, with the mouth closed and open. The closed-mouth view (Fig. 15-B) shows flattening of the left condyle, with an anterior beak. *The left condyle is larger than the right; it has moved more anteriorly than its mate.*

ascending ramus of the mandible was felt throughout its entire extent by the absence of the covering masseter muscle and parotid gland. Mouth opening was full. The chin deviated to the right as the patient opened her mouth, and swung again to the mid-line on full-mouth opening. The left temporomandibular joint crepitated as it moved. On mouth closing, a reverse path was followed.

To the syndrome of unilateral condylar hypertrophy and palatal and dental inclination, may be added that of naevus flammeus and glaucoma.

Naevus Flammeus, Glaucoma, and Condylar Asynchronism Caused by Congenital Hypertrophy of the Condyle on the Side of the Naevus

Case 16: A woman, twenty-eight years old, opened her mouth two and one-eighth inches; the chin deviated to the right as she did so. The left temporomandibular joint crepitated on movement, but the right one was silent. Both condyles moved beyond the eminence, the left a little more than the right. The left condyle felt larger than the right one.

The left eye was glaucomatous and was operated upon at an undetermined time before examination in 1940. The large naevus is shown in Figure 15-A. The left side of the face was hypertrophic because of this vascular tumor. The left upper lip was enlarged and was inclined downward and laterally. There was similar obliquity of the hard palate. The left upper teeth overlapped the lower ones and were inclined downward and laterally.

Dystonic Asynchronism

In dystonia, asynchronous condylar motion may be noted when the muscles of the head and neck are involved. This may be attributed to spasticity of the pterygoideus externus and of the other jaw muscles.

CASE 17: A boy of eighteen had a moderate form of generalized dystonia. There were occasional twisting movements of the head and neck to the right or left. He found it difficult to hold the head in the mid-line. The neck was elongated, or giraffe-like. His speech was dysarthric. He opened his mouth fully, but there was left lateral deviation of the jaw. The asynchrony of condylar motion was shown by more rapid advance of the right condyle. In mouth closing, the left condyle retreated first. The left mandible was less developed than the right. He moved the jaws from side to side easily, with some exaggeration over the normal.

Other Conditions

Disturbances of the temporomandibular joint also occur in malocclusion of the teeth, in prognathism in which the condyle is brought forward, and in recession in which it is placed more posteriorly. The edentulous mandible shows a posterior condylar position and relative lessening of the angle of the jaw.

NOTE: Cases 5, 15, and 17 were seen on the Service of Dr. Leo Mayer, Hospital for Joint Diseases, New York City.

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A REVIEW OF THE INCEPTION AND DEVELOPMENT OF A TYPE OF REPARATIVE SURGERY ADAPTED TO BODILY MECHANICS

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This exposition, to justify its title, must include my initiation to Orthopaedic Surgery. This was in 1882 when, as a House Surgeon at the Boston City Hospital, I assisted Dr. Bradford in the resection of a tuberculous hip joint.

The outlook for further progress was not encouraging, since the only clinic available for practical training was that of the Children's Hospital, then in the embryo stage of its development, which had no occasion for my services.

Thus for lack of other opportunity, I began, perforce, what was to become a perennial course of self-education, based on the observation of the gait and posture of the *walkers on the street, in an attempt to interpret the instinctive adaptations to locomotive* disability and to deformity. This ambulatory, and what might be termed peripheral, approach to the subject proved to be greatly to my advantage, since it opened a new therapeutic field, capable of progressive and productive development.

My first utilization of this material was on the question of the spontaneous outgrowth of deformities of the lower extremities in childhood. This was the generally accepted impression, which I disproved, at least from the aesthetic standpoint, by tabulating the proportion of the adolescent and adult walkers who had not outgrown childhood deformities.[2] This indicated the advantage of corrective treatment, while the bones were in the plastic stage, by "means at the command of mothers and nurses".

The second essay in adaptive therapeutics was of far greater importance, since it was the first of consecutive contributions to the type of surgery under review. A young woman, disabled by painful flat feet, was sent to me for treatment. I had never heard the subject mentioned in medical school, and the textbooks gave it scant consideration. The deformity was likened to a broken bridge, which might be made serviceable by supporting it from beneath.

In my inexperience I consulted a member of the staff of the Children's Hospital, which had added a brace shop to its equipment, as to the proper procedure. He instructed me to make an outline tracing of the feet and to send it with a pair of shoes to the hospital, where sole plates would be constructed. This episode represents fairly the therapeutic standing of an important disability, often mistaken for rheumatism, and otherwise relegated to the care of cobblers and mechanics.

At this unsatisfactory juncture, I came upon a report of the dissection of a flat foot by Humphry. This was enlightening, since it demonstrated clearly that the deformity was not the result of a direct breaking down of the arch, but was incidental to a subluxation of the astragalus on the os calcis, which deflected the strain of weight-bearing and locomotion to the inner border of the foot. Thus it appeared that the primary and significant physical sign of the disability was not the lowered arch, but the loss of the normal incurvation of the inner contour of the foot, which implied a persistence of the passive attitude of abduction. The flat foot, therefore, was a later stage of a progressive disability, of which the predisposing and exciting causes were improper postures in standing and in locomotion, of which my observation of walkers on the street had furnished abundant evidence. It was obvious, therefore, that the essential of effective treatment was not the propping up of a broken arch, but the restoration of the normal relations of the leg and foot.

To make this conclusion operative, a leverage brace was modeled on a plaster cast of the corrected foot. It was designed to provide lateral rather than vertical support, thus to check deformity at its source and, by suggestive pressure on the inner aspect of the

foot, to prevent the predisposing outward rotation of the limb. It served, therefore, as contrasted with sole plates and stiffened shoes, as a positive factor in reconstructive treatment, since by maintaining the proper relation of the power of the fulcrum, locomotion was utilized as a recuperative exercise. When the normal posture enforced by the brace had become automatic, the brace was discarded.

This essay on the positive treatment of a neglected disability and on its prevention by the timely recognition of its predisposing causes was published [3] and I was invited to present the subject to The American Orthopaedic Association. This society, the first of its class, had been organized under a temporary truce between its factions, in order to qualify for membership in the Congress of American Physicians and Surgeons, to be held at Washington in the autumn of 1888.

The admission of The Association to the Congress as an entity was a tacit recognition of its emancipation from the restrictions of scope and method with which the term "orthopaedic" was associated. It was therefore a point of departure from which progress in normal and consecutive development may be reckoned,—progress which eventually transformed an ill-conditioned and factitious specialty into an integral branch of surgery. The meeting had also a reciprocal influence on the development of what may be termed adaptive surgery, for it was evident that a further application of the principles that had proved effective in the reconstructive treatment of the flat foot required a better understanding of bodily structure and function.

I undertook, therefore, an intensive study of anatomy, and tested my acquirement by passing the examination for membership in the Royal College of Surgeons. On my return from England, I migrated to New York, where orthopaedic surgery had been first defined by Mott in 1841, where Sayre had established its first professorship in 1859, where Knight had founded the first hospital of its class in 1863, where The American Orthopaedic Association had been organized in 1887, and which was the storm center of the controversy as to whether mechanical or operative surgery should be the dominant factor in its title.

Immediately upon my arrival, I joined the staff of the Hospital for the Ruptured and Crippled. I was assigned to the Out-Patient Department, which in the number and variety of its patients offered a striking contrast to my past experience; for it represented the development of Knight's system of "surgico-mechanics", which included every physical disability symptomatically amenable to bandaging and bracing, irrespective of its character or of the age or sex of the patient. Thus,. at this juncture, a definite purpose, an increased capacity for interpretation, and abundant material provided a dependable basis for the consecutive development of the type of surgery with which this paper is particularly concerned.

Naturally, my first interest was in establishing a comprehensive treatment of the so-called flat foot for which the Outdoor Department provided a fertile field. In 1889 this condition was not noted in the Hospital report. In 1929, approximately 5,000 new cases of the disability were recorded. The construction of positive supports had become the chief industry of the mechanical department, and treatment, designed to restore normal function, was the most distinctive feature of the Service.

In the meantime, my interest in observing and interpreting peculiarities of gait brought to light fracture of the hip in childhood. Thus I was enabled to demonstrate the technical efficiency of anatomical mechanics in a class of cases in which the treatment of the fracture was the only consideration.[3]

In the development of the treatment in a comprehensive sense, I had the further advantage of an approach from the standpoint of hip disease, with which it had much in common. Thus the plaster spica, the changes in posture, the interpretation of the physical signs as indicating the progress of repair, and the use of the caliper hip brace in cases in which early locomotion was required were adaptations to the fracture and the patient which made effective treatment practicable and established the positive standard.[5]

My appointment to the Staff in 1889 was timely from another standpoint, for Gibney, who had succeeded Knight as Surgeon-in-Chief, had made a radical departure from the established routine by improvising an operating room. It may be noted that the surgery of the period was purely corrective in its scope and that the great majority of the operations reported by Gibney were of the subcutaneous type. Yet this modest innovation, in the development of which my training and inclination qualified me to assist, was the propelling force in the transformation of a home for crippled children into a representative hospital.

In 1903 a ward for women was established, and in 1917 men were admitted to the Hospital Service. In 1889 there were but 190 admissions to the Hospital; in 1929 the number had risen to 4,113. In this year (1929) there were 3,522 operations. Of these, 1,875 were classed as orthopaedic and 1,647 were credited to the hernia department. Thus by the natural development of its resources, in which the indoor and outdoor departments supplemented one another in a reciprocal service, the Hospital had become the leading exponent of constructive surgery for both the ruptured and the crippled.

In the two examples of adaptive surgery that have been presented, operative intervention is an occasional and supplementary expedient. In a third illustration it is the positive and introductory feature. This is the operation of astragalectomy and backward displacement of the foot for paralytic calcaneus, which was then almost as much of a therapeutic derelict as the two instances cited.[5]

In a typical case, the patient limped about on the insecure support of a hypertrophied heel, to which the forefoot was a useless appendage. The astragalus was removed in order to reduce both the vertical and lateral deformity and to assure security by implanting the malleoli on the basic structure of the foot, thus changing a complex joint to a simple joint. The backward displacement reduced the adverse leverage and utilized weight-bearing on the contracted arch to restore symmetry. Finally and most important, the tarsus was brought beneath the anterior border of the tibia, thus providing the positive check to dorsal flexion essential to security in progression.

This readjustment of the statics and mechanics of the disabled member proved so effective in restoring relative stability that more than 2,000 of these operations for this and other forms of paralytic disability were performed during my term of service.

As a student of the range of operative intervention in a class of cases in which, as in this instance, the injury to function was irremediable, I had the advantage for many years of a continuous service in both the indoor and outdoor departments of the Hospital to supervise an operation from inception to conclusion, and thus, by comparison with the original condition, to estimate fairly from the patient's standpoint its functional utility.

Such comprehensive control is almost essential to the appraisement of the relative value of an operation, which in one instance may be designed to relieve the patient from artificial support and in another only to make such support more tolerable and effective.

Adaptive surgery has a wide range of availability. The three procedures cited to represent its principles illustrate, in order of presentation, the prime factors of artificial, anatomical, and operative mechanics correlated in the reconstructive treatment of three unrelated disabilities. Each of them has withstood the test of time or, specifically, the opposition proportionate to its divergence from the established practice, as best exemplified by the abduction treatment in which the divergence was of both method and standard. They may be accounted, therefore, as stable contributions to what has been termed "the transformation of orthopaedic surgery".

The ancient, ambiguous but irreplaceable term "orthopaedic", which for those who accepted its restrictions was an insuperable obstacle to progress, is now generally understood as indicating only a sphere of action. As such, it is especially concerned with impairment of bodily structure and function from any cause, and with prevention and cure, as well as with relief. This is a broad, ill-defined, expanding, and consequently only

partly charted therapeutic field, in which orthopaedic treatment, although it has no preferential jurisdiction, retains as a special attribute a "follow through". Thus a purposeful initiative is supplemented by equally purposeful after-care, which is often the determining factor in the result, if reckoned in terms of useful function.

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BONE-MARROW EMBOLISM FOLLOWING FRACTURE

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When fat embolism of the lungs and brain occurs, it most often follows fractures of the shafts of the long bones. In adults, the marrow of these bones consists largely of olein, which is a liquid at body temperature. Fat embolism occurs less frequently after fractures of the flat bones or fractures of the ends of the long bones; in these locations the marrow cavity is composed mainly of hemopoietic tissue. Although the historical, clinical, roentgenographic, and anatomical aspects of fat embolism are well known[3,4], and more than 600 cases have been recorded in the literature, only one case of associated bone-marrow embolism to the lungs has been reported[5]. Pulmonary embolism caused by marrow fragments has been described in eclampsia.[1] The occurrence of this process after skeletal trauma has been mentioned by MacCallum, without further comment. It seems probable that bone-marrow embolism, associated with fat embolism, occurs frequently after fractures. It would be necessary to examine the entire pulmonary tissue by microscopic sections in order to demonstrate the few fragments of marrow which have been liberated into the vascular system at the fracture site. The finding of such emboli in a few random sections of pulmonary tissue is purely accidental.

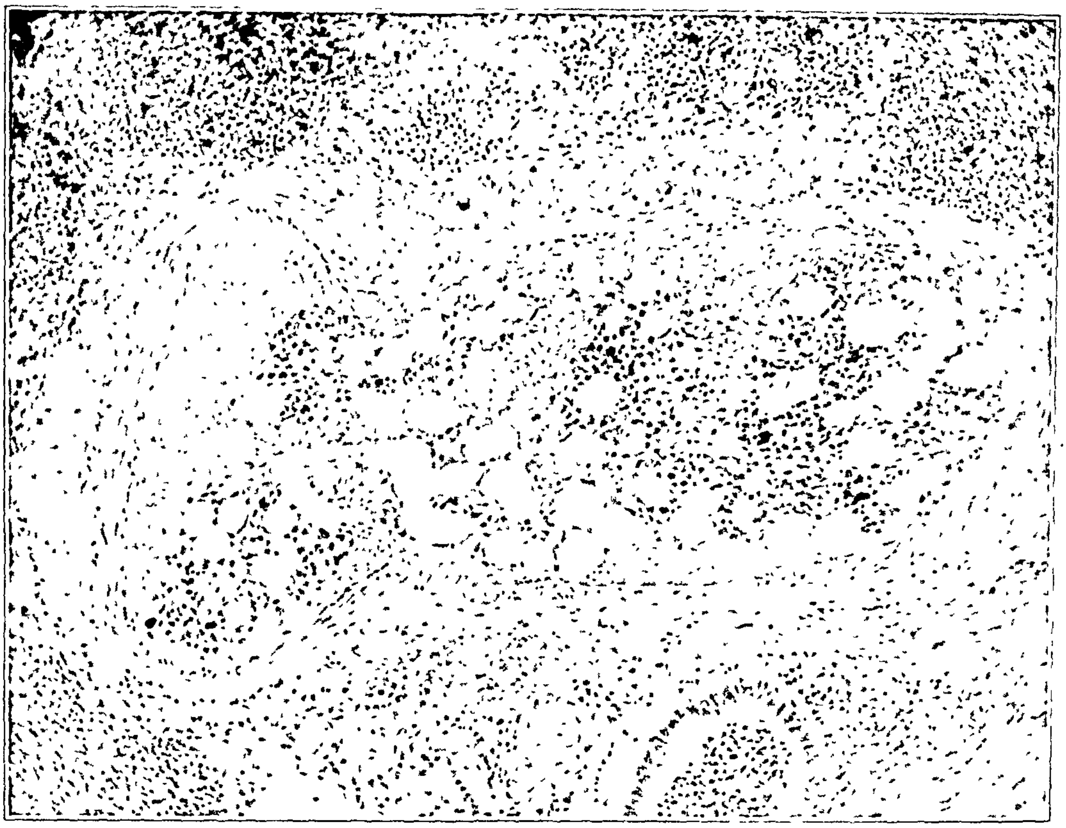

FIG. 1

Case 1. Hematoxylin and eosin stain (× 120).

CASE REPORTS

CASE 1. A white sailor, twenty-one years of age, entered the Hospital shortly after he had fallen from a door of a rapidly moving train. Upon admission, he was unconscious and his breathing was stertorous. There was profuse bleeding from the nose and mouth. Multiple lacerations of the right side of the scalp and an extensive laceration, extending into the lateral aspect of the right knee joint, were noted. Numerous superficial abrasions were present on the scalp, shoulders, elbows, and hands. There was an oblique fracture through the lower portion of the lateral condyle of the right femur. The patient's temperature was 103 degrees, the respiratory rate was 28, the pulse rate was 120, and the blood pressure was 115/60. During a seven-hour period, the patient had ten generalized convulsions, characterized by extension and stiffening of the extremities, flexion of the head to the right, and opisthotonos. The Babinski sign was positive bilaterally, and the knee jerks were increased but equal. His temperature gradually became elevated to 105 degrees, the respiratory rate increased to 50, and the pulse rate to 156. Death occurred thirty-nine hours after injury and thirty-four hours after the onset of convulsions.

At autopsy, the lungs were large, voluminous, tense, and firm. Both the pleural and the cut surfaces showed a distinct mosaic appearance, with alternating zones of marked congestion, hemorrhage, and grayish consolidation. A large amount of frothy, sanguineous fluid exuded from the cut surfaces. There was a mild subarachnoid hemorrhage over the cerebral hemispheres, most marked on the superior surface on the right side; similar hemorrhage was observed on the superior surface of the cerebellum. Multiple hemorrhages, one to four millimeters in diameter, were scattered throughout the cortex, the white matter, and the basal ganglia of the cerebral hemispheres; they were most numerous in the frontal lobes and on the right side.

Histological changes were limited to the lungs and to the brain. Staining with sudan IV showed the absence of lipid material in the lumina of the cardiac and renal blood vessels. The pulmonary arteries and veins, and the capillaries of the alveolar walls, were distended with blood. In one of the many pulmonary sections was a branch of the pulmonary artery, which measured approximately 370 by 950 micra. Its lumen was almost completely filled with a large fragment of well-defined bone marrow (Fig. 1). This consisted of numerous fat cells, erythropoietic cells, and myelopoietic cells, several megakaryocytes, and supporting connective-tissue cells. By serial sections, this segment of marrow could be followed in the lumen of the vessel for a distance of 70 micra. The marrow embolus had lodged at the bifurcation of the vessel, and extensions of it could be followed into the two branches. These branches measured 250 and 340 micra in diameter, and were almost completely filled with the embolic mass of marrow tissue.

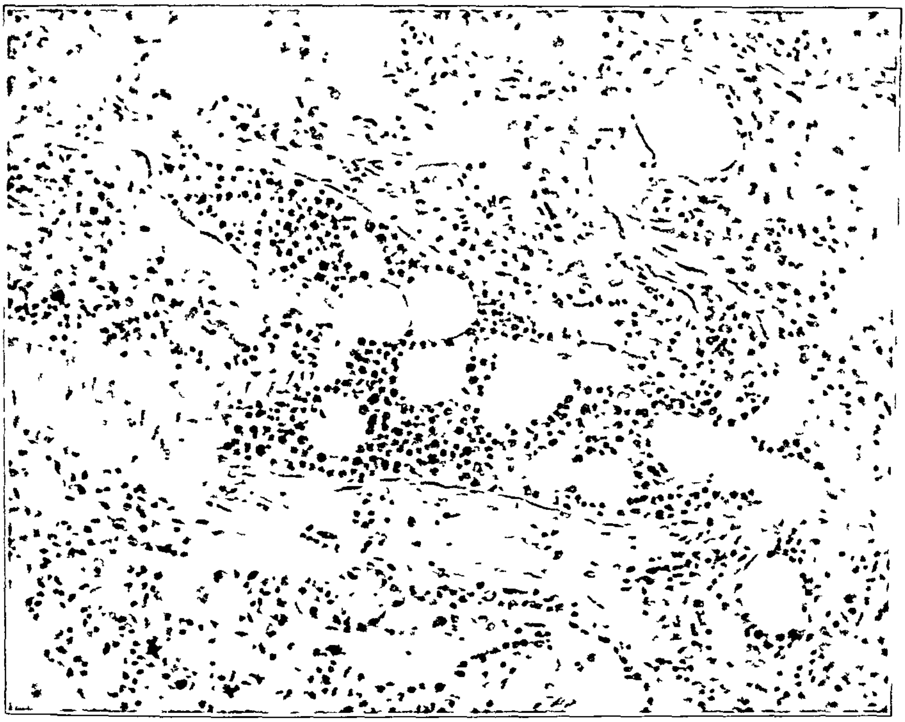

Fig 2

Case 2 Hematoxylin and eosin stain (× 180)

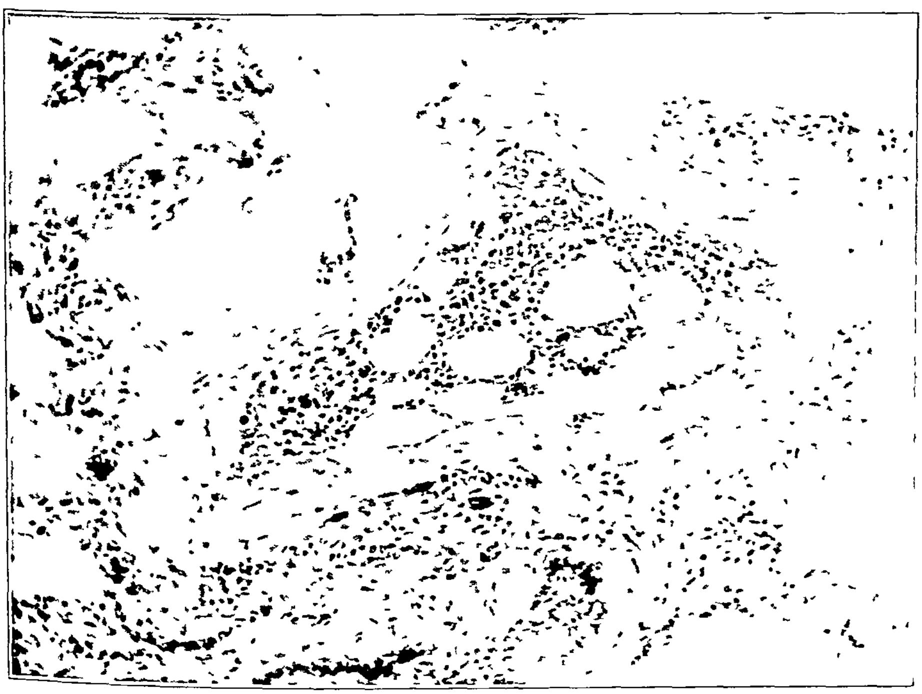

Fig 3

Case 3 Hematoxylin and eosin stain (× 180)

Most of the alveoli and the bronchioles were filled with seropurulent exudate. Others contained red blood cells, serous fluid, fibrin, and macrophages containing blood pigment. Staining with sudan IV demonstrated globules of neutral fat in the lumina of many of the larger pulmonary vessels and in the capillaries of the alveolar walls. Smaller lipid globules also lay in the alveolar spaces. Some had been ingested by macrophages and by neutrophilic leukocytes.

Many small hemorrhages were present in the cerebral hemispheres, most often in a perivascular situation. Moderate amounts of blood were present in the subarachnoid space. Many of the small cerebral arteries were distended, but empty. No lipid material within them could be demonstrated by staining with sudan IV.

Case 2. A white merchant seaman, forty-five years of age, was strangled while in an alcoholic state and was thrown 250 feet down a steep, rocky cliff, where he was found dead the following morning. At autopsy, there was anatomical evidence of strangulation and asphyxia. There were multiple fractures of the skull, sternum, left clavicle, mandible, right radius, ribs, and seventh thoracic vertebral body. Multiple lacerations and abrasions of the skin, cardiac contusion, and hepatic and renal lacerations were also noted. Inspection of the brain showed moderate subarachnoid hemorrhage, and numerous petechial hemorrhages were present throughout the white matter of the cerebral hemispheres. In addition to the subpleural asphyxial hemorrhages, both lungs were mildly congested and oedematous.

The capillaries of the alveolar walls were moderately distended with blood. Small amounts of serous fluid and numerous macrophages containing pigment were present in the alveolar spaces. Some of the alveolar spaces were emphysematous; others were atelectatic. Staining with sudan IV revealed only a few pulmonary vessels which contained lipid globules. In one of the many sections examined, the lumen of one branch of the pulmonary artery, measuring about 240 by 640 micra, was almost completely occluded by a fragment of bone marrow (Fig. 2). This was composed of well-defined erythropoietic and myelopoietic elements, and a few fat cells. There were no megakaryocytes. The marrow embolus could not be demonstrated in serial sections. No lipid material was evident in the lumina of the renal or the cerebral vessels, when stained with sudan IV.

Case 3. A white soldier, twenty-three years of age, collided with an automobile while he was riding a motorcycle. He was dead a few minutes later, upon arrival at the Hospital. At autopsy the following lesions were found: multiple comminuted fractures of the skull and the sternum; fractures of the left radius and ulna, the left femur, and the right tibia and fibula; contusions of the forehead, nose, lips, chest, and left shoulder; contusions of both lungs; lacerations of the left kidney; and subdural and subarachnoid hemorrhages.

The capillaries of the alveolar walls were mildly congested. Many alveoli were filled with red blood cells. Several sections of pulmonary tissue were made; one contained a single branch of a pulmonary artery, measuring about 215 by 400 micra, which contained a fragment of well-defined bone marrow (Fig. 3). This material almost filled the lumen and was composed of erythropoietic and myelopoietic elements, two megakaryocytes, and several fat cells. The embolus could not be demonstrated in serial sections. Although staining with sudan IV was not done on the cerebral, pulmonary, and renal tissues, there was no vacuolation of the vascular contents, which might suggest the presence of lipid globules.

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BILATERAL EXTRA-ARTICULAR ANKYLOSIS OF THE HIP JOINT

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A cadaver of a white male, who was thirty-eight years of age at the time of death, was found, during the course of its dissection by two members * of the first-year class in anatomy, to have bilaterally immobile hip joints. Complete exposure of the hip regions revealed that the immobility was due to well-developed, completely extra-articular arches of bone, located anterior to the joints (Figs. 1-A and 1-B). On each side the bony arch extended from the region of the anterior inferior iliac spine to the anterior surface of the femur. Both hips were fixed in the position of moderate flexion.

Roentgenograms, showing the relation of the bony arches to the hip joints, are reproduced in Figures 2-A and 2-B. Grossly and roentgenographically, the arches had the appearance of true bone. Sections from one of them were ground and mounted on slides. Microscopic examination proved that they were actually bony structures, rather than mere depositions of calcium salts (Fig. 3).

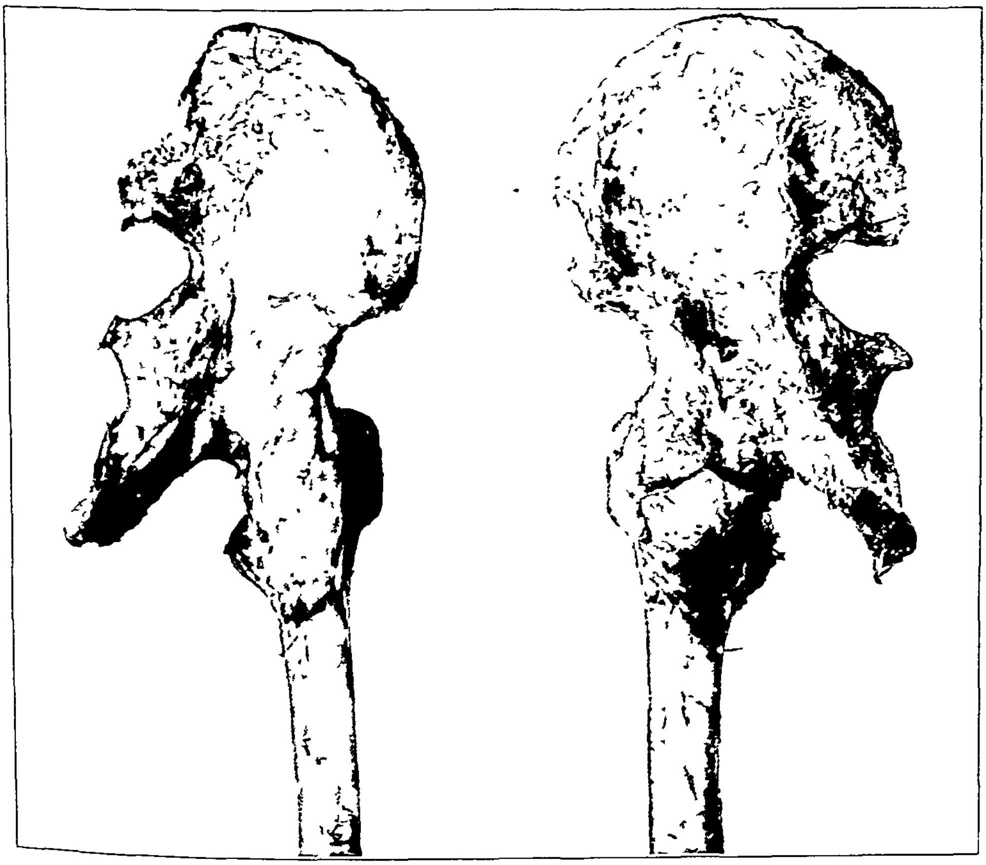

FIG 1-A

Photograph of left innominate bone and femur, showing the bony connection between ilium and femur

FIG 1-B

Photograph of right innominate bone and femur The bony process was fractured by forceful abduction of the thigh.

* Walter F. Anderson and Donn Richard Barber

The tendons of the iliopsoas and pectineus were not involved in the osseous process on either side. There was, however, considerable atrophy of the iliacus and pectineus, which was to be expected since no movement of the femur in relation to the pelvis was possible.

The bony arch on the right side was fractured when the students attempted to abduct and flex the thighs to facilitate dissection of the perineum (Figs. 1-B and 2-B). Subsequent to this fracture, the head of the femur was freely movable within the acetabulum. Examination of the joint on the left side showed that it also was free of any intra-articular ankylosing process.

The iliofemoral ligaments (Y-shaped ligaments of Bigelow) could not be demonstrated, although the posterior and inferior portions of the joint capsules were present and were normal in appearance. The positions and relationships of the bony processes were such as to make it seem probable that they might have developed as ossifications of these ligaments. The cross sections taken from the arch on the left side proved to be much more densely ossified in their deeper strata than in their more superficial (anterior) strata.

According to the available history, this individual entered the Colorado School for Mental Defectives at the approximate age of eight years and remained there for twenty-two years. The remaining eight years of his life were spent in the Colorado State Hospital. He was the third of eight children and weighed eleven pounds at birth; the birth was recorded as prolonged.

An undated note, made during his long stay at the School for Mental Defectives, described his gait as "slow, uncertain, and shuffling". Upon admission to the State Hospital his gait was again described as "slow and shuffling", with poor coordination. The diagnosis on admission was "mental deficiency—idiot".

During the last seven years of his life he was bedfast, very deteriorated mentally, and indifferent to his surroundings. Occasional convulsions were recorded during the last two and one-half years.

The only abnormality recorded during the course of the dissection, other than the externally

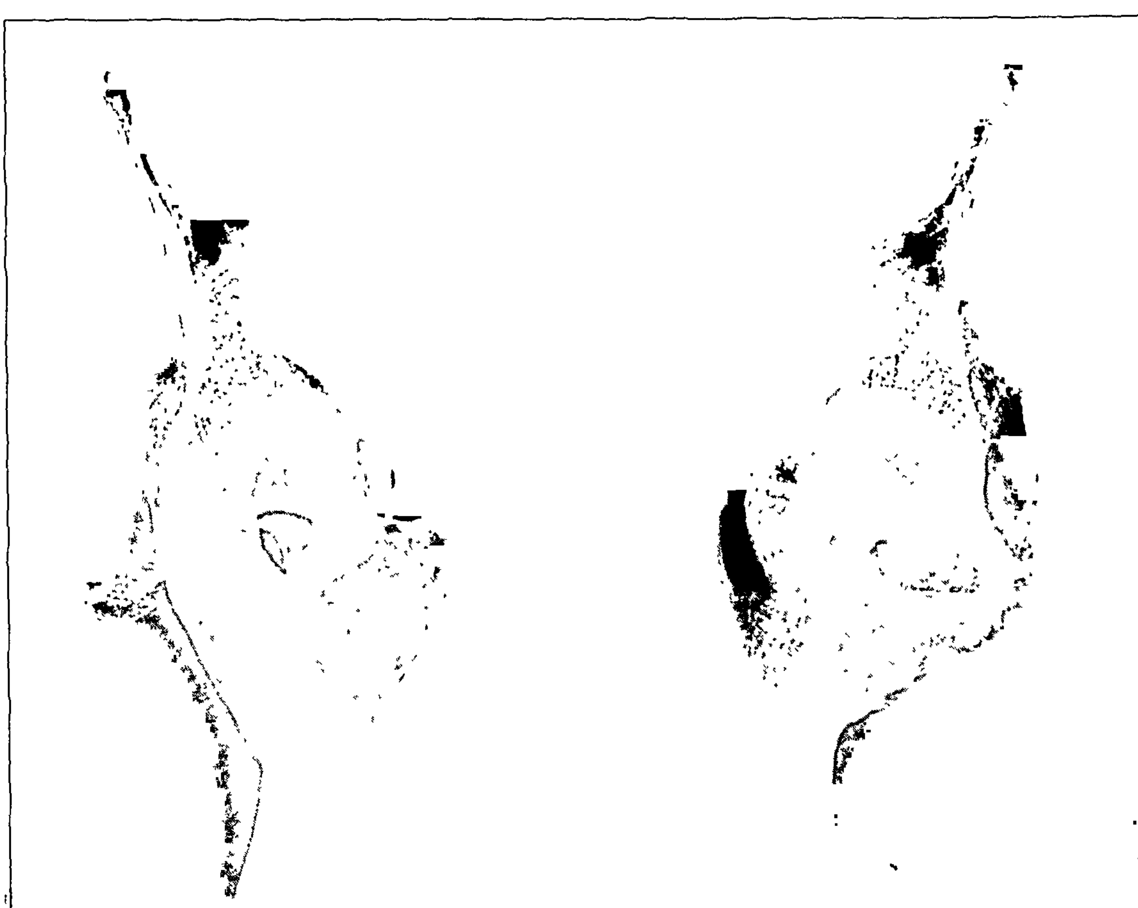

Fig. 2-A
Roentgenogram of left hip joint.

Fig. 2-B
Roentgenogram of right hip joint.

FIG. 3

Photomicrograph of a small area of a ground section from the bony process which was responsible for the extra-articular fixation of the right hip joint. Lacunae and canaliculi originally occupied by bone cells are clearly visible.

ankylosed hip joints, was a tremendously enlarged sigmoid colon. No other joints were similarly involved. The brain was not examined.

DISCUSSION

So far as could be determined, no report of a similar case of bilateral ossification of the iliofemoral ligaments has previously appeared in the literature. Kazakov and others have reported unilateral extra-articular ankylosis of the hip due to myositis ossificans, following some type of trauma.

Although the ossification that occurred in this case did not involve the connective tissue within the muscles—a finding which is supposed to be characteristic of the entity known as myositis ossificans—one is inclined to apply that name to it. In his discussion of myositis ossificans, von Pannewitz divided his ninety-four cases into three groups: those in which there was ossification of the joint ligaments and capsule following joint injuries (especially dislocation), those in which there was ossification of muscle as a result of a single trauma, and those in which ossification of muscle occurred after repeated slight traumata. In most of the cases described by von Pannewitz there was involvement of muscles. He did, however, refer briefly to a case in which there was ossification limited to the plantar aponeurosis, as a result of a crushing injury to the foot. The plantar aponeurosis is not considered to be a ligament, but its structure and function are similar to those of ligaments. Gruca stated that ossification of the joint capsule had been observed by a number of individuals who investigated myositis ossificans, but he failed to include specific bibliographical references to these investigators.

The various ideas as to the etiological factors in myositis ossificans have been discussed by Painter, Noble, and others. Bowers commented upon the frequency of the

condition in insane persons. Noble stated that most of the cases occur in males, during early adult life.

It is, of course, impossible to come to any definite conclusion as to the time of inception of the condition found in the cadaver described herein. The "slow, uncertain, and shuffling" gait noted at some time during his stay at the School for Mental Defectives was no doubt due, at least partially, to the ankylosis of the hip joints. There was no definite history of trauma that might have accounted for the condition.

There is a somewhat remote possibility that bilateral trauma, responsible for ossification of the iliofemoral ligaments, could have occurred at the time of birth. The prolonged labor may have been complicated by uterine inertia, which necessitated podalic version and extraction. Excessive traction exerted through the relatively undeveloped hip joints may have resulted in injury to those portions of the capsules which eventually thicken to form the iliofemoral ligaments. It is then necessary to assume that the subsequent growth of the pelvis and femora was accompanied by proportionate growth of the bony arches. That such growth could occur does not seem an unreasonable assumption, since there is a separate center of ossification for the anterior inferior iliac spine.

The history of convulsions might be considered significant in this case, if it had extended over a long period, but it does not seem likely that bony processes so well developed as to appear to have been associated with the normal ossification of the pelvis and femora could have been developed during the last two and one-half years of the subject's life. It might be suggested that the ligaments ossified during the prolonged period (seven years) during which he was bedfast and completely inactive, but this would preclude any connection between the bony formation and his manner of walking. Furthermore, all normal processes of ossification in the pelvis should have been complete at the time he became bedfast.

Whether an ossifying diathesis was associated with the mental derangement in this individual, as mentioned by Bowers, cannot be determined. It would seem that other sites of abnormal ossification would probably have been found, if the process had been the result of such a diathesis.

Spondylitis adolescens (Strümpell-Marie disease) was considered as a possible explanation for the ossification of the iliofemoral ligaments in this case. It was ruled out because of a lack of fixation in the sacro-iliac joints which, according to Blair, are usually the first to be attacked in this disease.

Note: The author appreciates the cooperation of F. H. Zimmerman, M.D., Superintendent of the Colorado State Hospital, who furnished the available history of this case. The bone sections were prepared by H. M. Kingery, Ph.D., and the illustrations by Glenn Mills; their help is gratefully acknowledged.

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A BILATERAL ANOMALY OF THE WRIST

Report of a Case

BY MAJOR R. D. BUTTERWORTH AND CAPTAIN W. E. DANER

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An unusual type of congenital deformity of the wrists, unique in the experience of the authors, was observed. The deformity was bilateral, with fusion of all the carpal bones and of the second, third, fourth, and fifth carpometacarpal joints on the right; and fusion of the capitate and hamate bones on the left.

A perusal of available textbooks and periodicals revealed a case reported by White [1] of bilateral congenital fusion of the capitate and hamate. He states that such fusion is rare, as judged by the paucity of reported cases.

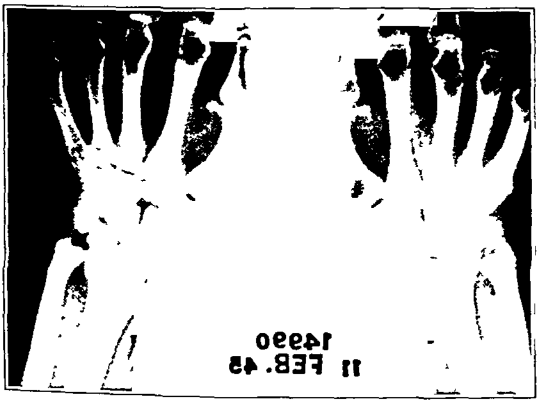

Fig. 1-A

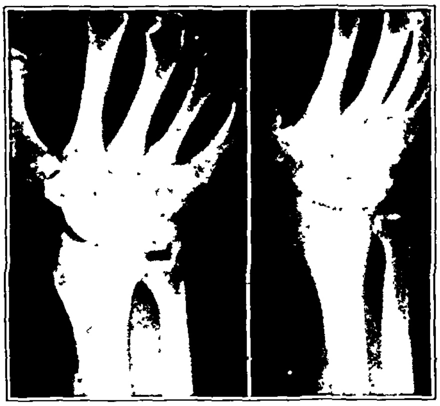

Fig. 1-B

Fig. 1-A: Shows fusion of all carpal bones and of the second, third, fourth, and fifth carpometacarpal joints on the right. The capitate and hamate on the left are fused.
Fig. 1-B: Additional views of right wrist, showing fusion.

CASE REPORT

An infantryman, twenty-three years of age, entered the hospital with the complaint of pain in his right wrist. There was no history of recent trauma, but he had injured the same wrist one year before, while playing with a medicine ball. Several weeks of immobilization had resulted in complete relief. There was no history of infection of this or of any other joint.

Physical examination was essentially negative, except for about 10 degrees of limitation in flexion and extension of the right wrist, and complete fixation of the carpometacarpal joints, demonstrated by efforts at compression of the hand. There was no apparent weakness, deformity, or tenderness A blood Kahn test was positive; all other laboratory studies were normal.

Roentgenograms of the right wrist, taken in several positions, showed complete intercarpal fusion, as well as fusion of the second, third, fourth, and fifth carpometacarpal joints. On the left, the capitate and hamate only were fused (Figs. 1-A and 1-B).

It was believed that the abnormalities were congenital, since there were neither history nor signs of infection; the trauma had been slight; fractures, old or new, could not be demonstrated; and this amount of fusion has not been seen even after severe compound fractures of the wrist. The changes were not characteristic of syphilis, although there was a positive history of this infection of four years' duration.

The function of the wrist was so good and the discomfort so slight that treatment was not instituted

1. White, E. H.: Bilateral Congenital Fusion of Carpal Capitate and Hamate. A Case Report. Am. J. Roentgenol., 52: 406–407, 1944.

FRACTURE-DISLOCATION OF THE MID-TARSAL AND CUBOIDEONAVICULAR JOINTS

Report of a Case

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An unusual type of fracture-dislocation of the foot—the result of a severe crushing injury—was seen recently. The dislocation, associated with multiple small fractures, was a medial displacement at the mid-tarsal joint (Chopart's joint) in which the navicular was displaced farther on the talus than was the cuboid on the calcaneus. Thus, there was a diastasis between the navicular and cuboid, and the dislocation was in the form of a T. By roentgenogram, the displacement at the horizontal arm of the T (the mid-tarsal joint) was readily seen (Figs. 1-A and 1-B), but the vertical arm between the navicular and cuboid was only demonstrated at operation. Key and Conwell [1] state that the mid-tarsal

Fig. 1-A

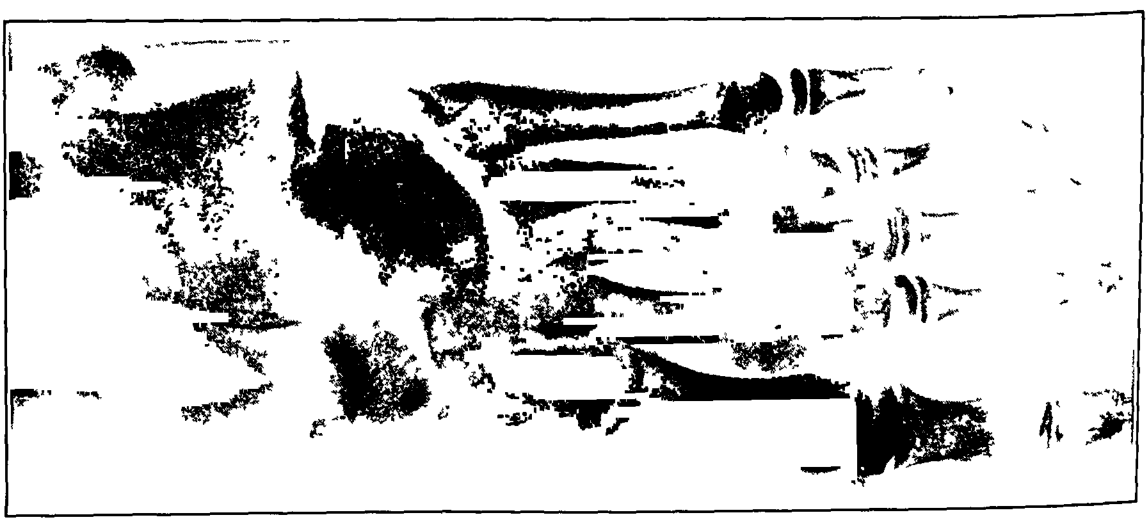

Fig 1-B

Roentgenograms reveal the position of the dislocated bones on admission. The medial displacement of the navicular and cuboid is well demonstrated.

dislocation is "a rare lesion", and the presence of the diastasis in this case would seem to contribute to the rarity.

CASE REPORT

An eleven-year-old boy was seen in the Clinic on March 2, 1945 with a painfully swollen left foot. He stated that twelve days previously he had been riding a pony and that the animal fell and rolled on his left foot. Roentgenograms revealed a fracture-dislocation of the talonavicular and calcaneocuboid joints with possible fracture of the third cuneiform bone and incomplete fractures of the necks of the second and third metatarsals. Because of the time which had elapsed since the injury, open reduction was elected and the patient was operated upon the following morning.

The talonavicular joint was opened through a dorsomedial incision, one and one-half inches long, and the joint space was freed of organizing fibrous tissue by sharp dissection. Reduction was then attempted with the aid of a skid, but resistance was encountered and it was felt that there must be a block at the calcaneocuboid joint. Accordingly, the calcaneocuboid joint was exposed through a one-inch lateral incision and the fibrous tissue was removed. It became evident that there must be a diastasis between the navicular and cuboid bones. The dorsal cortices of both the navicular and cuboid were fractured and, when a crocheted cotton ligature was pulled up through awl holes between these bones, it tore through the osteoporotic bone. A stainless-steel screw was inserted into the medial aspect of the navicular, through a large drill hole, and tapped into the cuboid; the pull-up action of the screw was utilized to reduce the diastasis. Then the dislocation at Chopart's joint was reduced easily, and position could be maintained with minimum pressure.

Fig 2-A

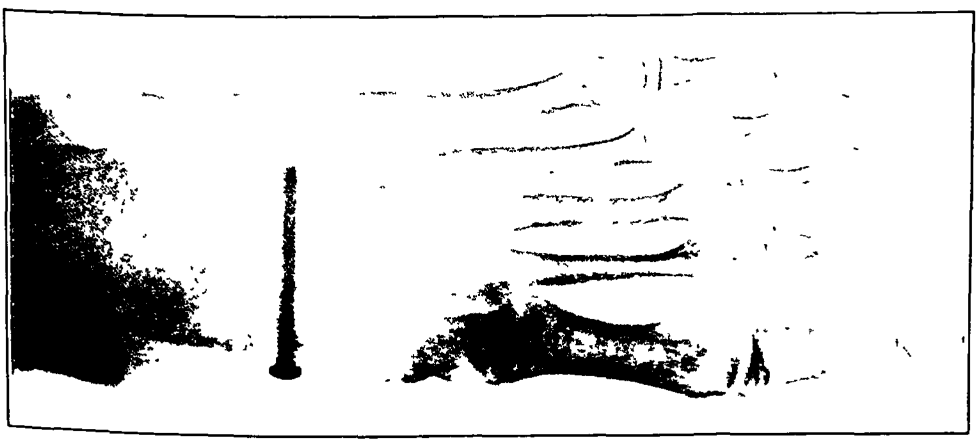

Fig. 2-B

Showing the position four months after operation. The bones are in relatively normal position.

A skin-tight cast was applied from the toes to the tibial tubercle. Seventeen days later a walking iron was added to the cast, and the patient was allowed to bear weight. Four weeks later, when the cast was removed, the wound had healed. Four months after operation the patient walked with a normal gait and the foot was asymptomatic (Figs. 2-A and 2-B). Approximately 25 per cent. of the pronation-supination of the foot was lost. The fractured necks of the second and third metatarsals healed with minimum angulation, which is not clinically significant.

The immobilization of joints by rigid internal fixation is usually not advocated for the treatment of fractures or dislocations. In this case, however, it was the only means at hand for maintenance of the reduction. The case is reported because of the good result obtained and the minor degree of limitation of motion.

1. KEY, J. A., AND CONWELL, H. E.: The Management of Fractures, Dislocations, and Sprains, Ed. 3. St. Louis, The C. V. Mosby Co., 1942.

AVULSION OF THE ISCHIAL TUBEROSITY

REPORT OF A CASE

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The paucity of cases reported in the literature would indicate that avulsion of the ischial tuberosity occurs rarely. In 1937 Cohen reported a case, and he reviewed three cases which had previously been recorded. McMaster has recently reported an additional case.

CASE REPORT

A white male, twenty-four years of age, was seen in the Orthopaedic Clinic of the Station Hospital; he complained of pain in his left buttock of eight years' duration. He gave the following history: While playing football at the age of sixteen, he stumbled to the ground and a fellow player fell on top of him. He did not remember the exact nature of the fall. A sudden, severe pain in the left buttock first developed at that time, and his left lower extremity became very painful on weight-bearing. He was examined by a physician, who recommended a period of rest in bed. No roentgenograms were made. The patient was confined to bed for from six to seven weeks. He limped for "a number of months" after the injury; with every step there was associated deep-seated pain in his left buttock. Gradually, this pain on weight-bearing subsided. He gave no history of acute aggravation of symptoms by any subsequent trauma, either direct or indirect.

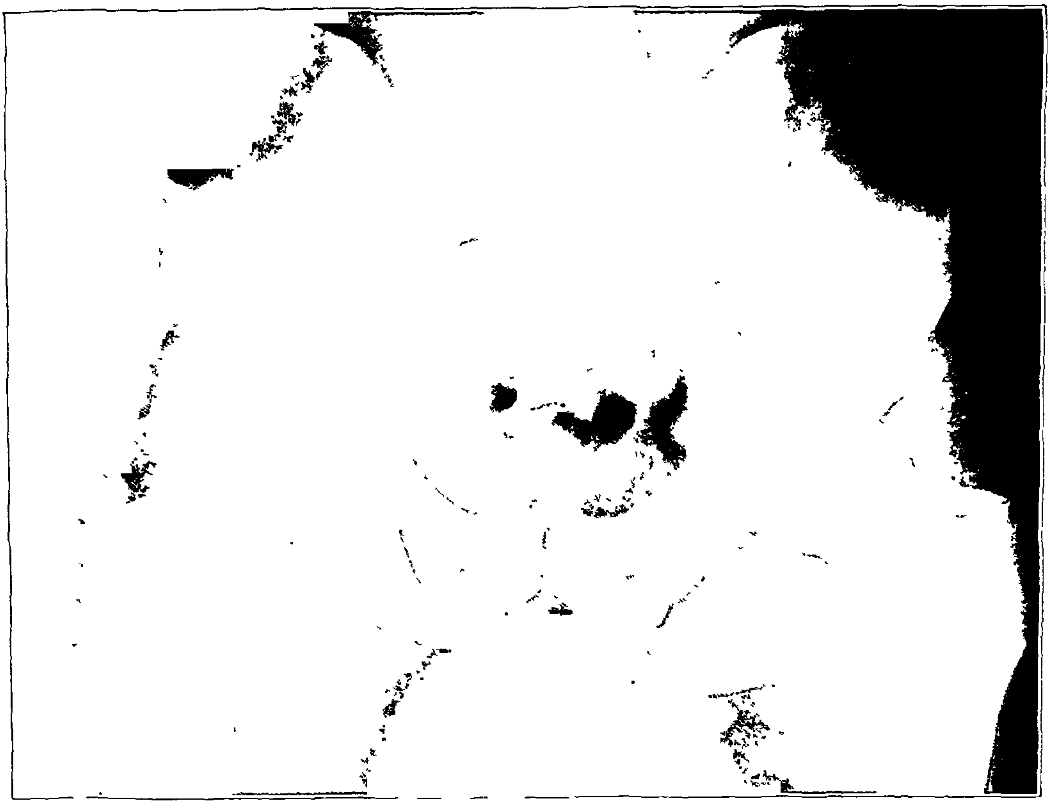

FIG. 1

Anteroposterior view of the pelvis, showing avulsion of an enlarged crescentic secondary epiphysis of the left ischial tuberosity.

When examined in the Orthopaedic Clinic, the patient complained that stooping evoked a moderate amount of pain at the site of his previous injury; that, if he sat on his left side for any length of time, an ache of progressive intensity developed; and that weight-bearing on his left lower extremity was painful, when he was physically burdened.

Physical examination revealed a well-developed white male, twenty-four years of age. His posture and gait were normal. Inspection of the buttocks revealed no asymmetry. Although there was no tenderness on palpation over the left ischial tuberosity, heavy percussion produced some deep-seated pain. The epiphysis was rigidly fixed and the range of motion of the left hip joint was normal. Forced flexion of the thigh on the abdomen, however, caused a moderate degree of "pulling" or "tearing" pain in the left buttock. Forward bending evoked the same complaint. When compared with the right lower extremity, the left mid-thigh was atrophied one inch and the left calf was atrophied one-half inch. Both lower extremities were of equal length.

Roentgenographic examination revealed a large crescentic secondary epiphysis of the left ischial tuberosity, ununited to the body of the ischium. The apposing surfaces were irregular in contour. A small area of calcification above the superior border of the fragment was interpreted as ossification of a previously existing hematoma.

This patient was given diathermy, but remained ambulatory. He was assigned to limited duty, and was advised to refrain from strenuous activity. No significant change was observed in his condition during the two months in which observation was possible.

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ISOLATED FRACTURE OF THE PISIFORM BONE

Report of a Case

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From the Orthopaedic Section, Station Hospital, Camp Howze, Texas

Fracture of the pisiform bone is a rarity in medicine, if one may judge from the very few cases of this condition which have been reported. The first known case occurred in 1847. Jaeger collected eleven cases in the literature, and in addition reported a case which he had observed. Two cases were reported by Jean and one by Briggs, making a total of approximately sixteen cases.

The exact mechanism involved in the production of fracture of the pisiform bone has never been defined clearly. Exhaustive studies by Jean and Solcard, however, indicate that the most probable mechanism is that of hyperextension of the wrist, with the forearm in pronation and adduction. Jean and Solcard observed an accidental fracture which occurred during hyperextension and adduction. It is evident that both of these mechanisms, that is, adduction and pronation, are strikingly similar.

Doubtless there are many cases of pisiform fracture which have not been reported, and perhaps a great many others which have gone undetected; but, due to the rarity of the condition, the following case is presented.

CASE REPORT

A white soldier, twenty-three years of age, reported at the Orthopaedic Clinic on May 23, 1944. He stated that three days previously, while he was running to the mess hall, he stumbled and fell on his outstretched left hand, striking it against a stone on the ground. Examination revealed abrasions of the left thumb and the left thenar aspect of the thumb. There was point tenderness over the volar aspect of the left wrist, overlying the pisiform bone. No crepitus was noted. Roentgenograms of the left wrist revealed a fracture of the pisiform bone, without displacement. A roentgenogram of the right wrist, taken for comparison and to rule out pisiform secundarium (accessory pisiform) was found negative.

A lightly padded circular plaster cast was applied to the left forearm and hand, with the wrist in the position of slight palmar flexion and ulnar deviation. The metacarpophalangeal joints were not immobilized. This patient was treated in the Out-Patient Clinic and returned to light duty. It was necessary to reinforce the cast on June 15. On June 22, the cast was removed and a roentgenogram was reported as follows: "Re-check of the left wrist fails to visualize the fracture line of the pisiform, apparently due to healing". Immobilization was discontinued at this time. The patient was observed one week later, and at this time he apparently had full function and no residual disability.

Fig. 1

Fracture of pisiform bone of left wrist.

The authors believe that roentgenographic studies should be made of every wrist injury, even though it may appear extremely slight. Three views are essential. Delayed treatment or failure to recognize such fractures may result in prolonged treatment and unnecessary disability. The treatment recommended consists of immobilization by plaster cast or molded splint, with the wrist in a position of mild palmar flexion and ulnar deviation.

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SUBMENISCAL FOREIGN BODIES IN THE KNEE

REPORT OF TWO CASES

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The diagnosis, localization, and surgical removal of loose bodies within the knee present interesting and difficult problems. It is not sufficiently well recognized that foreign bodies, both endogenous and exogenous in origin, may be located underneath the menisci.

Geist has reported two cases in which chondro-osseous bodies were removed from beneath the anterior horn of the lateral meniscus. Bizarro described a case in which a fragment of glass was found beneath the posterior horn of the lateral meniscus. The author has published his experience with a case in which fragments of a sea shell were removed from the submeniscal compartment of the posterior horn of the medial meniscus.

The first case to be presented revealed a fragment of glass underneath the anterior horn of the lateral meniscus. In the second case, a chondro-osseous body was discovered beneath the anterior horn of the medial meniscus.

CASE REPORTS

CASE 1. E. A., a white woman, seventy-nine years old, appeared in the Emergency Room of the New Haven Hospital on November 11, 1944, with the complaint of a cut on the left knee. Shortly before admission, the patient had tripped on a curbstone while carrying a glass jar of ground coffee. She had fallen upon the left knee.

Examination revealed a ragged, transverse laceration, eight centimeters in length, on the anterolateral aspect of the left knee. The interior of the knee joint was easily seen through the wound. Coffee grounds and dirt were embedded in the laceration, but no glass was seen. It was noted that the patella was higher than normal. No active extension of the knee was possible. There was no evidence that the peroneal nerve had been injured. Roentgenograms (Fig. 1) showed a radiopaque object, presumably glass, embedded deeply within the substance of the proximal end of the tibia.

The diagnosis, therefore, was compound wound of the knee joint, compound fracture of the tibia caused by a fragment of glass, and laceration of the patellar ligament. After the usual prophylactic dose of mixed tetanus and gas-bacillus antitoxin had been given, the patient was brought to the operating room.

The wound was cleansed and débrided. Numerous fragments of glass were removed from the surrounding soft tissue, as was also the large fragment which was buried deeply in the tibia. Careful inspection of the wound led to the conclusion that all the glass had been found. Experience with the previous case, mentioned above, led the operator to suspect that some foreign body might be concealed beneath the meniscus. Therefore, the submeniscal compartment of the anterior horn of the lateral meniscus was explored. A piece of glass about two centimeters in length was uncovered and removed. The patellar ligament was repaired and the wound was closed without drains, following a copious irrigation of the knee joint and wound with saline. A cast was applied. The postoperative course was uneventful, and the wound healed by first intention. Eight weeks later the cast was removed and physiotherapy was started. The patient was last seen on August 7, 1915. Extension and flexion were complete. There was no pain or limp. Muscle strength and stability of the joint were normal.

Comment: In this case, a large exogenous foreign object was completely concealed by a meniscus. If the operator had not been conscious of the possibility that the submeniscal compartment can contain and conceal foreign objects, contaminated material would most certainly have been left in the knee, and the result might have been much different.

CASE 2. M. G., a fifteen-year-old white boy, entered the Clinic with the complaints of pain in the right knee and a swelling on the medial aspect of the right knee joint.

About two and one-half years previously, the patient had noted a small "growth" on the anteromedial aspect of the right knee in the region of the proximal end of the tibia. The localized swelling had increased in size, until six months before his present admission to the Clinic. There had been no pain in the knee during the first two years after the appearance of the tumor. During the next six months, an aching pain had developed, which was unrelieved by rest and was unaffected by activity. During the same period, there occurred intermittent attacks of severe knife-like pain, which lasted for from one to two minutes. These attacks increased in severity and frequency until, at the time of admission, several exacerbations were being experienced each day.

FIG. 1

Case 1. Dense foreign body may be seen in the region of the tibial tuberosity. This body is not the one found beneath the anterior horn of the lateral meniscus at operation. The lateral view added nothing of significance.

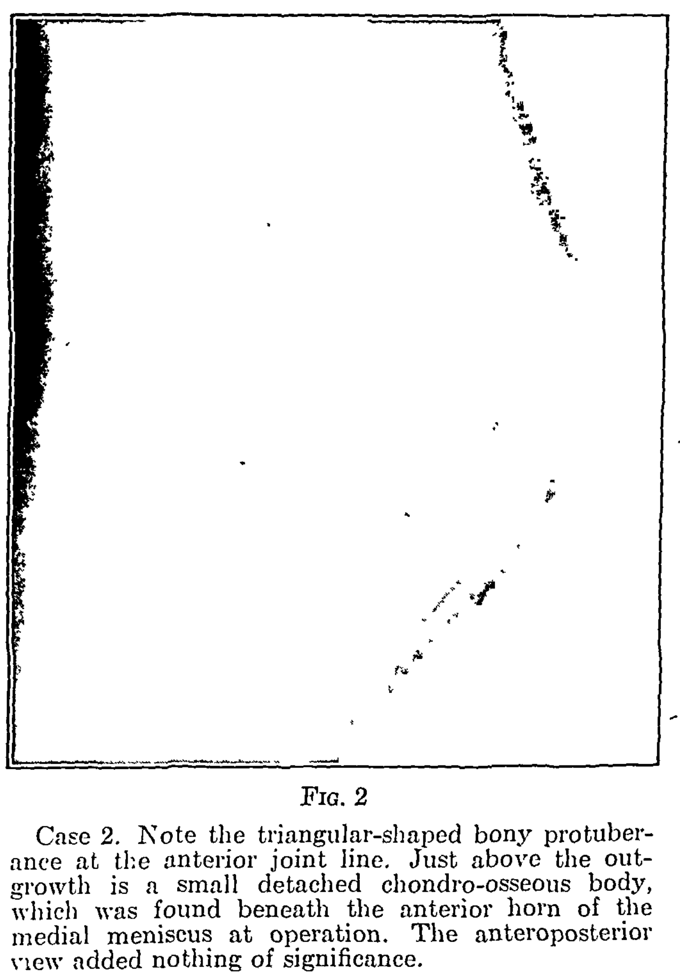

FIG. 2

Case 2. Note the triangular-shaped bony protuberance at the anterior joint line. Just above the outgrowth is a small detached chondro-osseous body, which was found beneath the anterior horn of the medial meniscus at operation. The anteroposterior view added nothing of significance.

SPLINT FOR THE TREATMENT OF MALLET FINGER

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The purpose of this paper is to describe a splint for the correction of avulsion of the extensor tendon of a finger from its insertion into the base of the distal phalanx.

Mallet finger usually occurs as a result of forced flexion of the distal interphalangeal joint while the extensor tendon is contracted, but it may follow a sharp blow directly over the insertion of the tendon. The injury is sustained frequently by individuals engaged in sports in which a hard ball is caught.

If the injury is not treated adequately by proper reduction and fixation, the ability actively to extend the distal interphalangeal joint is lost, and a flexion deformity develops, with characteristic baseball finger. Watson-Jones points out that the proximal interphalangeal joint becomes hyperextended, due to the uninhibited pull of the extensor tendon slips to the proximal portion of the middle phalanx, and that this complication may prove more incapacitating than the deformity at the distal joint.

The principle of treatment of mallet finger is to hyperextend the distal interphalangeal joint and to hold the finger in this position until the fracture has healed. Many splints have been devised to immobilize the avulsion fracture, as described by Lewin, Forrester and McLean, and Rider. Plaster casts have been used, but present the disadvantages that the plaster may become soft, the casts are usually bulky, they are difficult to apply properly, and they soil easily.

Recently, the junior author suffered a sprain-fracture of the distal phalanx of the right index finger. Because of hospital duties, it was necessary for him to have a splint which could be adjusted easily and which would not be damaged greatly by moisture. The splint which was devised is made as follows:

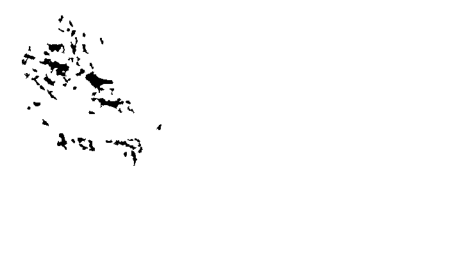

FIG. 1

Composite picture of parts of splint.

A tongue-blade is cut to the length of the injured finger, and two notches, one-quarter inch wide and one-eighth inch deep, are cut about half an inch from the curved end. A right-angle wedge, the width of the tongue-blade, with one-inch sides and a hypotenuse of approximately one and one-half inches, is cut from a large cork. A shallow groove, suitable to cup the distal phalanx, is cut in the hypotenuse of the wedge. The cork is then placed on the tongue-blade, as illustrated in Figure 1. Fixation of the cork

FIG. 2

Splint applied, with initial layer of adhesive strapping.

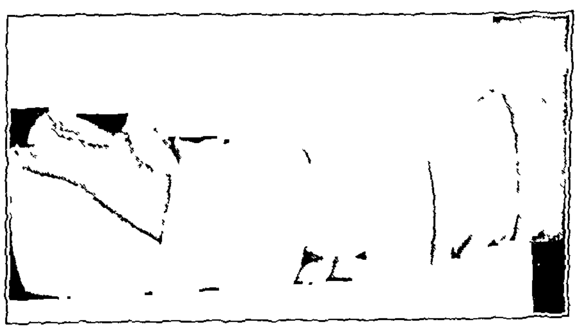

FIG. 3

Splint maintained with complete adhesive dressing.

* Orthopaedic Fellow, The National Foundation for Infantile Paralysis, Inc.

o the blade is maintained with glue and adhesive strapping. The distal phalanx of the njured finger is placed on the cupped wedge; the remaining phalanges rest on the flat, dhesive-covered tongue-blade. A thin layer of felt is placed over the dorsal surface of the listal interphalangeal area and the finger is fixed with half-inch adhesive strapping, with he distal joint in hyperextension (Fig. 2). One strip of the adhesive strapping is then cut vith two butterfly slots. When the strapping is passed over the dorsum of the finger, the utterfly notches are fitted into the notches which had previously been cut on either side of the tongue-blade, to prevent slipping of the splint on the finger. The splint is further ecured by running adhesive strapping beyond the most proximal part of the tongue-blade o the interphalangeal web, as indicated in Figure 3. Hyperextension of the distal joint is hus controlled and maintained.

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AN IMPROVED PEDAL FOR ELECTRICAL APPARATUS USED IN SURGERY

BY COLONEL PHILIP LEWIN

Medical Corps, Army of the United States

From the Mayo General Hospital, Galesburg, Illinois

Most bone surgeons who use the electrically driven saw, or other electrical apparatus, have had difficulty at times with the ordinary foot pedal. The cage, or pedal house, shown in Figure 1, was devised in order to avoid tipping, slipping, or moving of the pedal.

When the surgeon wears foot covers to protect his shoes, or wears muslin leggings, it is imperative that he be sure-footed. The presence of the cage minimizes the danger of accidentally stepping on the pedal, and eliminates uncertainty in locating the apparatus. It is of value in the use of the electrical saw and other apparatus, such as the Bovie electrocoagulator. It should have a wood or lead base, to avoid moving around too easily.

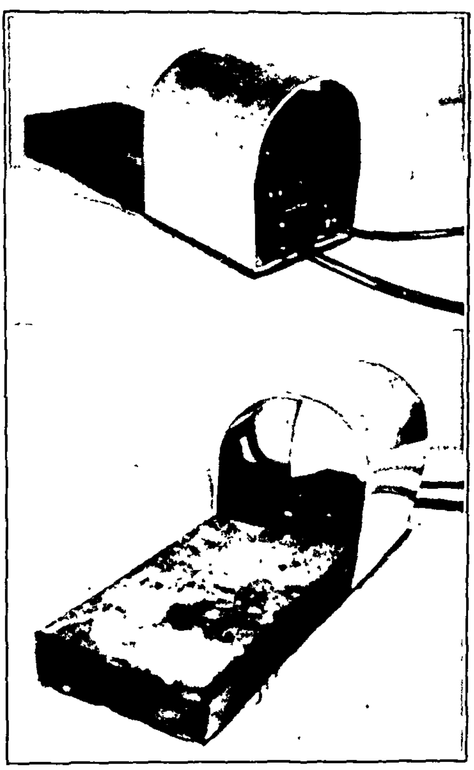

FIG. 1

Aluminum housing for electrical apparatus.

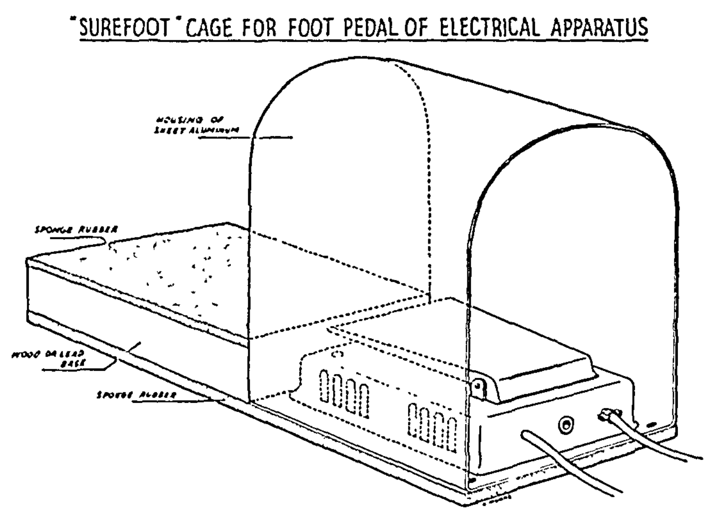

FIG. 2

Sketch showing construction of apparatus.

The cage (Fig. 2) was constructed by Staff Sergeant Harry Burger, in charge of the Orthopaedic Shop of Mayo General Hospital, who describes it as follows:

"The housing for the safety switch is made from sheet aluminum. It is five inches wide and six inches high, and is formed from one piece of aluminum, five and one-half inches wide and nineteen and one-half inches long.

"The foot platform is made of wood, covered on the top and bottom surfaces with a quarter-inch sheet of sponge rubber; the bottom piece covers the lower surface of the entire assembly.

"The aluminum housing is riveted to the base plate of the switch, which may be easily removed and later screwed back into place.

"The connecting strip of metal joins the wood platform to the housing assembly. The piece is three thirty-seconds of an inch by fourteen and one-half inches in size, and is screwed to the center of the undersurface of the wood piece and riveted to the base plate of the switch."

SPLINT TO CORRECT DEFORMITY RESULTING FROM INJURY TO ULNAR NERVE

BY MAJOR ARTHUR M. PRUCE
Medical Corps, Army of the United States

"Typical claw hand" is the textbook description for the deformity which frequently results from injury to the ulnar nerve. Due to muscle imbalance, the ring finger and the little finger are hyperextended at the metacarpophalangeal joints and are flexed at the interphalangeal joints. In addition, the little finger is abducted. Should the extensor muscles be permitted to shorten and the peri-articular tissues to become fibrosed, the resulting contracture will respond, if at all, only to prolonged and intensive treatment. In addition, the danger of joint subluxation and exaggeration of the deformity is constantly present.

This deformity can be prevented by early splinting, combined with guarded passive motion, which should be repeated several times daily. To offset the shortening of the extensor muscles and the bowstringing of the paralyzed intrinsic muscles, especially the lumbricales, the fourth and fifth fingers must be maintained in flexion at the metacarpophalangeal joints. The little finger must be adducted to prevent an abduction deformity, which leaves an interspace between the fourth and fifth fingers due to pull of the extensor digiti quinti proprius. This annoying deformity causes the little finger to catch on such things as pockets.

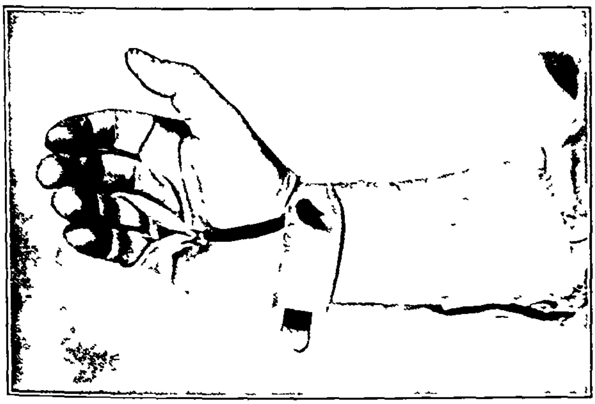

Fig. 1
Palmar view of splint in position.

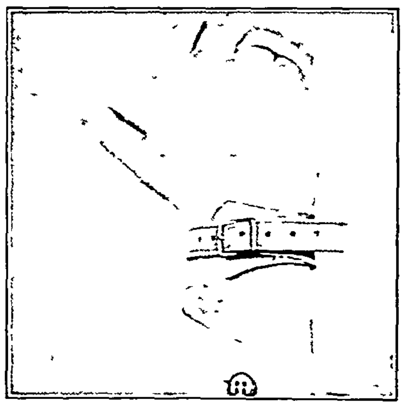

Fig. 2
Wrist band and finger cuff of splint.

A simple splint, consisting of a soft leather cuff, encircles the proximal phalanges of the ring finger and the little finger and is attached to a wristlet by a rubber band, with the line of pull toward the navicular. Splinted in this manner, the metacarpophalangeal joints are flexed to approximately 90 degrees and the little finger is supported in adduction. Shortening of the extensors is prevented, paralyzed intrinsic muscles cannot be overstretched, and active exercise is possible from a physiological position. The splint should be worn until recovery is complete, or until hope of recovery is abandoned.

The splint is of no value in an established claw deformity with secondary contractures of the joints, and it is useless in those cases in which the transverse metacarpal arch of the involved digits has been broken by excessive manipulation. Follow-up studies on the splinted hands have been difficult to carry out, but the results that have been obtained thus far justify this type of splint.

INFECTION OF THE KNEE JOINT BY *CLOSTRIDIUM WELCHII*

Report of a Case

BY CAPTAIN WOODROW W. LOVELL

Medical Corps, Army of the United States

The following case is presented because of its interest and rarity.

A private in the Infantry, eighteen years of age, was wounded by a shell fragment on February 19, 1945, while in Germany. The penetrating wound at the point of entrance on the medial aspect of the right knee was débrided and the shell fragment, which was embedded in the medial condyle of the femur, was removed at an evacuation hospital shortly after the injury. After 40,000 units of penicillin had been instilled into the joint space, the synovial membrane of the knee joint was closed. The skin and the deep fascia were left open, the wound was packed with vaseline gauze, and a long cylindrical plaster cast was applied. Forty thousand units of penicillin was given intramuscularly every four hours for seventy-two hours.

Seven days later, the patient was evacuated to a general hospital in England. He appeared to be perfectly comfortable, and his temperature, pulse, and respiration were normal.

Three days after the patient had been admitted to the hospital, his cast was removed and the right knee was found to be moderately swollen. Thirty-five cubic centimeters of blood-tinged fluid was aspirated from the knee; one per cent. procaine infiltration anaesthesia was used. The wound on the medial aspect of the knee was dressed and a cast was applied. Two days later the patient complained of severe headache, nausea, and slight pain in the right knee. His temperature was 103 degrees, the pulse rate was 130 per minute, and the respiratory rate was 22 per minute. His cheeks were flushed and he appeared to be in a toxic condition. A general physical examination was entirely negative, except for a soft apical systolic murmur. The white-blood-cell count was 33,000, with 88 per cent. polymorphonuclear leukocytes.

The patient had not improved by the following day, and the pain in the right knee had increased in severity. A window was cut in the cast, and the knee was found to be swollen, tender, and hot. A second aspiration yielded sixty cubic centimeters of pus. Fifty thousand units of penicillin was instilled into the knee joint, and 30,000 units was given intramuscularly every three hours. The pathologist reported that a smear made from the specimen which had been aspirated from the knee showed large gram-positive bacilli, with apparent encapsulation. The culture was reported on the following day to contain a pure growth of *Clostridium welchii.* It was pathogenic to the mouse.

By parapatellar incisions, the knee joint was then opened on its medial and lateral aspects. The synovia was thickened, and seventy-five cubic centimeters of the same type of pus was evacuated from the joint. Fifty thousand units of penicillin was placed in the joint space and the joint was left open. The knee was immobilized in a posterior splint. The pus which had been removed from the knee at the time of operation was also reported, after culture, to contain *Clostridium welchii.*

Therapy included the intramuscular injections of penicillin and the instillation of 40,000 units of penicillin into the joint daily. Sulfadiazine, in a dosage of one gram every four hours, was administered orally, and 20,000 units of antitoxin for gas gangrene was given intramuscularly every four hours. The sulfadiazine level was maintained at eight milligrams per 100 cubic centimeters. Transfusions of whole blood were given as supportive therapy.

Although the patient's temperature continued to be elevated for several days, his general condition appeared to be much improved and there was little pain in the right knee. He was instructed to do quadriceps-setting exercises during part of each hour. Drainage from the knee ceased after two and one-half weeks, and the operative skin incisions were closed secondarily. Physical therapy and active knee motion were begun one week later.

Roentgenograms of the right knee showed minimum destruction of the articular cartilage. The range of motion at the time of evacuation to the Zone of Interior was from 180 to 160 degrees.

Education Section

PROGRESS REPORT OF THE JOINT COMMITTEE ON POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY *

BY RALPH K. GHORMLEY, M.D., ROCHESTER, MINNESOTA

In his Chairman's Address before the Section on Orthopaedic Surgery of the American Medical Association in 1944, Dr. Guy Caldwell sounded the challenge to orthopaedic surgery, to be met in furnishing training to those men coming out of the Armed Forces who desired to complete their qualifications for the examinations of The American Board of Orthopaedic Surgery.

Dr. Caldwell estimated that approximately 900 medical officers were being drawn into contact with the specialty of orthopaedic surgery, and he predicted that more than half of these men would complete their training after the War. In the same address, Dr. Caldwell predicted that the number of men certified in orthopaedic surgery within the next five or ten years would be doubled or perhaps trebled, until it reached 2,000 to 2,500 men in the United States.

In the fall of 1944, after consultation with members of the Committee on Postgraduate Training in Orthopaedic Surgery of The American Academy of Orthopaedic Surgeons, the officers of The Academy of Orthopaedic Surgeons, and the officers of The American Orthopaedic Association decided to form a joint committee representing these two bodies, whose duty it would be to develop plans to meet the obvious challenge.

The list of available services for training orthopaedic surgeons, of the Council on Medical Education and Hospitals of the American Medical Association, showed eighty-four services so approved. Of them six were approved for three years of training, thirty-eight were approved for two years of training, and forty were approved for one year of training. These services offered facilities for 223 men in resident training. It was obvious to the Joint Committee that the list did not include all hospitals and institutions in this country where facilities for training orthopaedic surgeons should be available.

For this reason the Joint Committee decided to carry on a survey of its own to determine as nearly as possible where the facilities and personnel existed by which the number of residencies accredited for this training could be enlarged. The country was divided into a number of districts and the Committee asked certain orthopaedic surgeons to report on the facilities in their districts. After completion of the survey, the Committee met and reviewed the findings. Three facts were obvious: (1) A number of residencies in institutions, while having been depleted by the Orders of Procurement and Assignment, were functioning smoothly and could be expanded readily; (2) the staffs in a number of services which formerly had been well organized for teaching had been so depleted that training of residents had had to be abandoned and; (3) a number of institutions had the facilities and personnel, as well as the work, to make a creditable teaching service, but were not organized and not accredited.

By letters, personal visits, and conversations, the staffs of all hospitals in which the services seemed to the Joint Committee suitable for training orthopaedic surgeons have been urged to organize a teaching program and, if they had not already done so, to seek approval of the Council on Medical Education and Hospitals of the American Medical Association and of the Committee on Hospitals of The American Board of Orthopaedic Surgery.

Besides Dr. Caldwell's prediction of the number of men seeking additional training, the results of the pilot questionnaire sent by Lieutenant Colonel Lueth to the medical officers in the services were watched carefully. The earlier report from Lieutenant Colonel Lueth's office indicated that 297 additional residencies would be needed, if the officers were discharged at once. However, if these officers were dismissed over a period of two years, 127 additional residencies would be required. In his final report, Lieutenant Colonel Lueth [3] noted that 611 men wanted training in orthopaedic surgery. Of these, 487 desired long courses, and it was stated that 432 also wished to become recognized specialists.

In a later article [2] on postwar planning, an estimate of the probable required expansion of present teaching facilities was given. A tabulation indicates that the estimated additional postwar residencies required in orthopaedic surgery, if demobilization occurred at once, would be 444. The estimated additional residencies required, if demobilization extended over a period of time, was 201. It was found that 521 medical officers desired future certification by The American Board of Orthopaedic Surgery.

With these statistics in mind, the Joint Committee on Postgraduate Training in Orthopaedic Surgery has been doing everything possible to improve and extend the facilities to meet the demand. There are now approximately 400 residencies in orthopaedic surgery in the United States, which have been ap-

* Read before the meeting of The American Academy of Orthopaedic Surgeons, Chicago, January 22, 1946.

proved formally or provisionally by the Council on Medical Education and Hospitals and by The American Board of Orthopaedic Surgery. Several others are in the process of organization and should be functioning within a few weeks. Much effort has been put forth by many individuals and hospital services as well as medical schools to build up their resident-training program in such a manner as to retain their approved status and to have something definite to offer the returning veterans. The Committee cannot express too much appreciation of the tireless efforts of its colleagues over the country, who have helped so much to broaden the program of training.

The Joint Committee had hoped from its earliest meeting to be able to set up a Registry through which all applications could be filed, and thus to be able to advise the applicants of what supplemental training they would need to complete the requirements of the Board, and to inform them as to the services that would fill their needs. Due to inability to find adequate personnel to staff such a Registry, its formation has been delayed. However, within a short time a Registry will be set up and running. Dr. A. R. Shands, Jr. will be in charge and will carry on this work for the next few months at least. It is hoped that this will help to expedite the placement of those who are still seeking resident training.

In planning programs of training in orthopaedic surgery, it has been pointed out that the training must cover three phases: orthopaedic surgery for children, orthopaedic surgery for adults, and the surgery of trauma to the extremities and spinal column. In addition to these, all complete training programs should provide facilities for a review of basic medical sciences. The importance of this review is recognized in all surgical specialties. Training should include also information concerning developments in other branches of medicine and surgery. The importance of sound knowledge of anatomy and surgical pathology has long been recognized; opportunities for review and study of these subjects should be made available to all in resident training.

In order to clarify its attitude and to furnish a minimal standard, the Board has drawn up plans for basic science training. [The portion of the Report covering these plans was published in the January issue of *The Journal* (28: 189–190, 1946).]

In many instances training in these various phases must be divided among several institutions. Such affiliations have been encouraged by this Committee. Some excellent training programs have been developed in this way. We believe the future training of orthopaedic surgeons will be carried on largely by means of such affiliations. Thirty-eight institutions now are organized for three years of training, while in 1944 only six existed. Others will be organized. At present, approximately 190 residencies are available for three-year training programs.

It should be stated clearly and emphasized that this Committee does not mean to imply that training must be divided arbitrarily along the lines indicated, but it must cover all of the recommended phases, whether they are completed separately or concurrently.

Some of the difficulties in setting up such programs in wartime have already been mentioned. One that has been called to our attention frequently is that in the past few years many services have had the smallest number of hospital patients in years. This was true particularly of orthopaedic services for children. The number was small because, with increased prosperity, many patients were cared for by specialists in private practice and were no longer cared for in the wards where teaching of residents is carried out. How long this condition will continue, and what effect the possible plans for compulsory health insurance may have on these services, cannot be anticipated. It is the belief of the Joint Committee, however, that services in hospitals in which charitable care is given may be expected to occupy a less prominent part in educational programs than in years past, and more patients will be cared for by specialists in private practice. With this idea in view, The American Board of Orthopaedic Surgery passed the following resolution in January, 1945:

> "In special instances, with the approval of the Committee on Resident Training, the Board will recognize for not over two years' training in Orthopaedic Surgery periods of training in which the candidate continues work in a hospital service with part time assistantship to an Orthopaedic Surgeon certified by The American Board of Orthopaedic Surgery, provided that the major part of his time is spent by the candidate in the hospital service".

In order that recognition of this type of training may be obtained, a statement of the plan in each individual case should be filed with the Secretary of the Board.

One other phase of the general problem has been discussed by the Joint Committee. Its importance is recognized, and it is our intention to cooperate in every way possible in the planning of resident training in orthopaedic surgery in the permanent hospitals of the Army, Navy, and Veterans' Bureau. We have communicated with those who are planning the resident-training program in these hospitals, and we will do all we can to further the program. It is the opinion of the Committee that it will be to the advantage of all orthopaedic surgeons that training in orthopaedic surgery in such hospitals as the Army, Navy, and Veterans' Service designated as hospitals for resident training be recognized.

The Joint Committee intends to develop some means whereby it may stimulate the continuation of

all efforts to improve the quality of resident training. Some services may fail in this program. However, we cannot encourage large numbers to take this training without first making sure that the quality of resident training will be excellent.

The Joint Committee is aware, too, of the place this country must occupy in furnishing postgraduate training to students from foreign countries. While the next year or two will see facilities taxed to the utmost to care for returning American veterans, in the next two or three decades more graduate students from foreign countries will be receiving training in the United States, and plans must be developed to take care of them.

Two factors have delayed the placement of veterans in residencies; the solution of this difficulty has not yet been found. One is that many places on services are being held open for men whose training was interrupted to enter Military Service. The other is that many who have filed applications for residencies have not been able to tell the exact time of their release from Military Service. It is hoped that with the establishment of the Registry these difficulties can be reduced to a minimum.

Our efforts will continue. We appreciate the helpful spirit of those who have cooperated so generously in efforts to increase the number of approved residencies. Further help will be necessary both from those and from others who are developing new services now. It is our purpose to continue to develop services where facilities and personnel exist, and to urge continued improvement in all those services already established. There is room for improvement and we must progress. The whole future of orthopaedic surgery depends upon an adequate number of training programs with progressive, up-to-date plans for training new orthopaedic surgeons.

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REPORT FROM THE COMMITTEE ON POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY AND THE OFFICE OF ORTHOPAEDIC INFORMATION

Following the January meeting of The American Academy of Orthopaedic Surgeons, the newly appointed Secretary took over the active work of this Committee from Dr. Ralph K. Ghormley, the Chairman, and set up at the Alfred I. duPont Institute in Wilmington, Delaware, an Office of Orthopaedic Information where a Registry has been established for orthopaedic residencies. Since the end of January, all communications coming to the Committee have been referred to this office for reply and action.

At the Academy meeting Dr. Ghormley reported that the files of the Committee at that time contained the names of 723 men desiring orthopaedic training. The lists of names had been compiled from the lists of applicants to the hospitals offering accredited training. These hospitals had received from ten to over 250 applicants each. During January a questionnaire was sent by Dr. Ghormley to each of these men in order to have on file with the Committee the following information: (1) a record of previous education, training, and experience prior to admission into Military Service; (2) a record of the training and experience received in Military Service; (3) the date of discharge from the Service; and (4) the applicant's desires concerning postwar orthopaedic training.

Four hundred and thirty-four of these questionnaires have been returned and grouped as follows: (1) men discharged from the Service and desirous of immediate training, 137 or 32 per cent.; (2) those desirous of training upon discharge in from three to nine months, 83 or 19 per cent.; (3) those recently inducted into the Service and desirous of training upon discharge, 48 or 11 per cent.; (4) those accepted for training, 140 or 32 per cent.; (5) those applying for training from foreign countries, including Canada, 18 or 4 per cent.; and (6) miscellaneous, 8 or 2 per cent. From these figures it can be seen that there are 220, or 51 per cent. of the total, who at the time of sending in the questionnaire desired orthopaedic training in 1946, but had not secured an appointment.

During the first week in February questionnaires were sent to the 110 single or combined orthopaedic services accredited for training, in order to obtain information on vacancies and the names of the appointees. The total number of accredited residencies is now 403. To date information has been received from ninety-two services, which have reported five vacancies, 365 appointments, and 290 names

of appointees. The eighteen services not yet heard from have thirty-eight residencies. On the basis of the services reporting, it can be stated that 99 per cent. of the appointments for training in accredited residencies in 1946 have been made, as of this date.

At the present time, this office has knowledge of eighty-eight civilian hospitals which have applied or are about to apply to the Council on Medical Education and Hospitals and The American Board of Orthopaedic Surgery for approval of orthopaedic training. These hospitals will have approximately 132 additional residencies, which, if approved, will increase the total accredited residencies to 535. Any hospital desiring tentative approval of its orthopaedic service should follow the procedure as outlined on page 585 of *The Journal of the American Medical Association*, March 2, 1946, "Temporary Approval of Residencies". The procedure is for the hospital to apply for tentative approval to the Secretary of the Council on Medical Education and Hospitals of the American Medical Association, and to the Secretary of The American Board of Orthopaedic Surgery, giving information concerning personnel, facilities, and educational program of the hospital service. Upon receipt of this application, the Secretary of the Board will take the necessary action to secure temporary approval by the Board for one year, and the Council will, during the course of the following year, arrange for an inspection of the hospital service by one of its representatives. If temporary approval is obtained, this may later be changed to permanent approval, provided that the Council and the Board give final approval to this training.

In addition to the accredited orthopaedic services in the civilian hospitals, there are now twenty Veterans Hospitals which have established, or are about to establish, orthopaedic residencies, and which, according to the present plan for the operation of residencies in the Veterans Hospitals, should receive temporary approval of their residencies. In the selection from the applicants for these residencies, veterans will be given first consideration. During the next two years the Veterans Administration hopes to more than double the number of hospitals giving orthopaedic training. The following is a list of these twenty Veterans Hospitals, with the name of the Chairman of the Dean's Committee to whom letters concerning appointments for orthopaedic residencies should be addressed.

State	*Schools*	*Chairman of Dean's Committee*	*Location of Hospital*
California	California, Stanford	Dr. Howard C. Naffziger Medical School, Univ. of California San Francisco 22, Calif.	San Francisco
	Univ. of So. Calif.	Dean Burrell O. Raulston U. of So. Calif. School of Medicine 3551 University Ave. Los Angeles, California	Sawtelle
District of Columbia	George Washington, Georgetown	Dr. Walter A. Bloedorn Geo. Wash. School of Med. 1335 H St., Washington, D. C.	Mt. Alto
Indiana	Indiana Univ.	Dr. Matthew Winters, Sec. 23 E. Ohio St. Indianapolis, Ind.	Indianapolis
Illinois	Northwestern, Illinois, Loyola	Dr. J. Roscoe Miller Northwestern Univ. Med. School 303 E. Chicago Ave. Chicago, Ill.	1) Hines 2) Vaughn
Kentucky	Louisville	Dr. Arnold Griswold Univ. of Louisville School of Medicine 101 W. Chestnut St. Louisville, Kentucky	Nichols Gen. Hosp.
Maryland	Johns Hopkins, Maryland	Dr. Alan N. Chesney Johns Hopkins University School of Medicine 710 N. Washington St. Baltimore, Maryland *OR* Dr. Robert U. Patterson Univ. of Md. School of Medicine Baltimore 1, Maryland	Ft. Howard
Massachusetts	Boston Univ., Harvard, Tufts	Dr. C. Sidney Burwell Harvard Medical School 25 Shattuck St. Boston 15, Mass.	West Roxbury
Michigan	Wayne University	Dr. Hardy A. Kemp Wayne Univ. College of Med. Detroit 1, Mich.	Dearborn
Minnesota	Minn. University	Dr. Harold S. Diehl Univ. of Minn. Med. School Minneapolis 14, Minn.	Minneapolis

State	*Schools*	*Chairman of Dean's Committee*	*Location of Hospital*
New Hampshire	Dartmouth	Dr. Rolf C. Syvertsen Dartmouth Medical School Hanover, N. H.	White River Jct., Vt
New York	Columbia, Cornell, N. Y. U., N. Y. College of Medicine, L. I. College of Med.	Dr. Willard C. Rappleye 630 W. 168th St. New York 32, N. Y.	Bronx
Ohio	Western Reserve	Dr. Jos. T. Wearn Western Reserve Univ. School of Medicine 2109 Adelbert Rd. Cleveland, Ohio	Brecksville
Oregon	Oregon University	Dr. D. W. E. Baird Univ. of Oregon Med. School Portland 1, Oregon	Portland
Pennsylvania	Pittsburgh Univ.	Dr. Williams S. McEllroy Univ. of Pittsburgh School of Medicine Bigelow Blvd. Pittsburgh, Pa.	Aspinwall
Tennessee	Tenn. University	Dr. O. W. Hyman Univ. of Tenn. College of Medicine 874 Union Ave. Memphis 3, Tenn.	Memphis
	Vanderbilt Univ.	Dr. Ernest W. Goodpasture Vanderbilt Univ. School of Medicine 21st Ave., S., at Edgehill Nashville 4, Tenn.	Thayer Gen. Hosp.
Texas	Southwestern	Dr. Tinsley Harrison Southwestern Med. College 2211 Oak Lawn Dallas 4, Texas	Ashburn Gen. Hosp.
Utah	Utah University	Dr. H. L. Marshall Univ. of Utah School of Medicine Salt Lake City, Utah	Salt Lake City
Virginia	Med. Coll. of Virginia	Dr. Harry J. Warthen, Sec. Medical College of Va. Richmond, Virginia	McGuire Gen. Hosp.

The Army and Navy have now designated five hospitals each in which orthopaedic training will be given to doctors from the Medical Corps of the Regular Army and Regular Navy. These services are now in the process of being organized and established.

This office has also had many inquiries (1) from physicians discharged from the Armed Forces who have completed their orthopaedic training and wish information regarding suitable locations for practice, and (2) from Diplomates of the Board concerning available trained assistants. At the present time, there are many communities which apparently are either overcrowded or about to be overcrowded with returning orthopaedic surgeons, while many other communities are sorely in need of orthopaedic specialists. It is hoped that this office may acquire enough information on locations for practice in orthopaedic surgery to establish a Registry for them, and thus help this situation.

Any suggestions concerning how the work of this Committee can be made more effective will be greatly appreciated by the Chairman, Dr. R. K. Ghormley, the Secretary, and the whole Postgraduate Committee.

A. R. Shands, Jr., M.D., Secretary

March 23, 1946

FELLOWSHIPS IN ORTHOPAEDIC SURGERY OF THE NATIONAL RESEARCH COUNCIL

Fellowships in Orthopaedic Surgery, administered by the Medical Fellowship Board of the National Research Council, will again be available for the year beginning July 1, 1946. This series of fellowships, supported by a grant from the National Foundation for Infantile Paralysis, Inc., is designed to provide opportunities for training and research in those basic medical sciences which will be of particular value in furthering progress in the field of orthopaedic surgery.

These research fellowships are open to citizens of the United States and Canada who are graduates in medicine and who have completed one or more years of hospital experience in clinical surgery. They are intended for recent graduates, not yet professionally established, who are planning to specialize in orthopaedic surgery.

Further particulars concerning these fellowships may be obtained from the Secretary of the Medical Fellowship Board, National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

The American Public Health Association has recently designated the following institutions as accredited to give the degree of Master of Public Health (Diploma of Public Health in Canada) for the academic year 1946–47: Columbia University School of Public Health, Harvard University School of Public Health, The Johns Hopkins School of Hygiene and Public Health, University of California School of Public Health, University of Michigan School of Public Health, University of Minnesota School of Public Health, University of North Carolina School of Public Health, University of Toronto School of Hygiene, and Yale University School of Medicine, Department of Public Health.

UNITED STATES PUBLIC HEALTH SERVICE

Appointments to fill vacancies in the Reserve Corps of the United States Public Health Service are now being made, and examinations for Regular Corps appointments will be held in April and May.

Physicians, dentists, and nurses are needed immediately for duty in hospitals, in the Tuberculosis and Venereal Disease Control programs, and in other activities of the Public Health Service.

In making the announcement, Surgeon General Thomas Parran stated: "For the physician, the dentist, and the nurse, the Public Health Service is unique in the variety of opportunities it offers. Not only does the person have the opportunity for outstanding service to the nation in the growing field of Public Health, but the opportunities for professional growth and development are almost limitless. There is clinical work in Public Health Service hospitals throughout the country. The importance of medical research is being emphasized today more and more, and in the Public Health Service research opportunities exist in both laboratory and the field."

Those interested in either immediate appointment in the Reserve Corps, or in taking the examination for the Regular Corps, should request application forms of the Surgeon General, U. S. Public Health Service, Washington, D. C., Federal Security Agency.

SHRINERS' HOSPITALS FOR CRIPPLED CHILDREN

A nationwide, five-point program to expand and accelerate its fight against all crippling diseases affecting children has been set into action by the Shriners of North America.

The new program has been developed through a series of recent meetings sponsored by the Imperial Potentate, William H. Woodfield, Jr., of San Francisco, and other members of the Shriners' Imperial Council; and approved by Dr. J. Albert Key, of St. Louis, president of The American Orthopaedic Association; member surgeons of the Association who serve as chief surgeons of the fifteen Shriners' Hospitals for Crippled Children, located in various cities of the country; and W. Freeland Kendrick, Chairman of the National Board of Trustees of the Hospitals.

The five phases of the new plan are:

1. The granting of scholarships, to be known as The Fellowships of the Shriners' Hospitals for Crippled Children, in orthopaedic surgery, to outstanding, qualified medical students.
2. An annual appropriation will be granted for scholarships in orthopaedic nursing. These nurses, in turn, will instruct and give encouragement to other nurses interested in specializing in the crippled children's field.
3. The establishment of a research project to probe further the sources, methods of treatment, and prevention of all crippling diseases attacking children.
4. The expansion of present facilities and equipment of the fifteen Shriners' Hospitals now in operation and the establishment of new hospitals in other localities.
5. The establishment of convalescent homes in connection with all Shriners' Hospitals. The installation of recreational and occupational therapy courses to assure continuing physical improvement and self-development after healing has been completed.

The wide scope of charitable work carried on by the fifteen Hospitals is revealed in a statement by Mr. Kendrick that operating expenses for the current year will be in excess of $1,000,000. The Hospitals and endowments represent an investment of about $45,000,000, he said.

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Annual Meeting of The American Orthopaedic Association will be held at Hot Springs, Virginia, June 27, 28, and 29, 1946, under the presidency of Dr. J. Albert Key. Headquarters will be at The Homestead Hotel.

The tentative program as submitted by the Program Committee is as follows:

THURSDAY, JUNE 27

Morning Session

The Calcaneovalgus Foot of Infancy.
Dr. J. E. M. Thomson, Lincoln, Nebraska.

The Definition of Human Locomotion on the Basis of Measurement, with Description of Oscillographic Method.
Dr. R. Plato Schwartz, Rochester, New York.

Hypermobile Flat Foot with Short Tendo Achillis. From Observations in the Canadian Army.
Dr. R. I. Harris, Toronto, Ontario, Canada.

Pre-Employment Back Examinations and Their Significance.
Dr. Steele F. Stewart, Honolulu, Hawaii.

A System for Splinting Hands for Radial, Ulnar, and Median Paralyses.
Dr. Sterling Bunnell, San Francisco, California.

Noon: Executive Session.

Afternoon Session

Symposium on the Intervertebral Disc.
Dr. Arthur G. Davis, Erie, Pennsylvania, *Chairman*.

FRIDAY, JUNE 28

Morning Session

Postgraduate Teaching in Orthopaedic Surgery.
Dr. Ralph K. Ghormley, Rochester, Minnesota.

Report of Committee on Infantile Paralysis.
Dr. Robert W. Johnson, Jr., Baltimore, Maryland, *Chairman*.

Newer Observations on the Experimental Contributions in Infantile Paralysis and Their Correlation to Pathological Facts. The Rationalization of Treatment of Infantile Paralysis on These Grounds.
Dr. Arthur Steindler, Iowa City, Iowa.

End Results of Bone-Grafting for Non-Union of the Carpal Navicular Based on the Study of 100 Cases.
Dr. Gordon Murray, F.R.C.S., Toronto, Ontario, Canada. (By invitation.)

President's Address.
Dr. J. Albert Key, St. Louis, Missouri.

Afternoon Session

The Evaluation of Cortical and Cancellous Bone as a Grafting Material; a Clinical and Experimental Study.
Dr. LeRoy C. Abbott, San Francisco, California.

Paper on a subject to be announced.
Mr. Harry Platt, F.R.C.S., Manchester, England.

Subtalar Arthrorisis for Certain Types of Flat Feet.
Dr. Allen F. Voshell,
Dr. Charles J. Basile,
Dr. William L. Waldrop,
Dr. Moses Gellman, Baltimore, Maryland.

Fracture-Dislocation of the Ankle with Fixed Displacement of the Fibula Behind the Tibia.
Dr. David M. Bosworth, New York, N. Y.

Medical Electronics. Electromyographic Studies of Muscle-Action Currents.
Dr. Nicholas S. Ransohoff, New York, N. Y.

SATURDAY, JUNE 29

Morning Session

Symposium on Treatment of Complications of Fractures of the Hip.
Dr. Philip D. Wilson, New York, N. Y., *Chairman.*

Noon: Executive Session.

It will be noted that there are fewer papers on the program this year. This change has been made in order to allow more time for discussion. It would be of help to the Program Committee if those who wish to discuss any of these papers would write to the Chairman, Dr. Lloyd T. Brown, 372 Marlborough Street, Boston, Massachusetts.

THE AMERICAN BOARD OF ORTHOPAEDIC SURGERY

Part I of the examinations will be given in New Orleans, Louisiana, May 3 and 4, 1946; in St. Louis, Missouri, and San Francisco, California, May 10 and 11, 1946; and in Philadelphia, Pennsylvania, May 17 and 18, 1946. They will not be repeated until the Spring of 1947.

Part II of the examinations will be given in Chicago, in January 1947, preceding the meeting of *The American Academy of Orthopaedic Surgeons.*

Correspondence and applications relative to Part I of the examinations should be sent to Dr. Guy A. Caldwell, 3503 Prytania Street, New Orleans 15, Louisiana. After July 1, 1946, all correspondence and applications for Part II should be sent to Dr. Francis M. McKeever, 1136 West Sixth Street, Los Angeles 14, California.

The Seventy-Fourth Annual Meeting of the **American Public Health Association** will be held in Cleveland, Ohio, the week of November 11, 1946.

The **American College of Surgeons** announces that arrangements have been completed for the holding of its Thirty-Second Clinical Congress at the Waldorf-Astoria, New York, September 9 to 13, inclusive. Plans include the usual extensive program of demonstrations, scientific sessions, panel discussions, symposia, forums, Hospital Standardization Conference, medical motion pictures, business meetings, and educational and technical exhibits, which will be held in the headquarters hotel, and operative and non-operative clinics in the local hospitals.

BARUCH COMMITTEE ON PHYSICAL MEDICINE

To advance and encourage research, teaching, and training in the field of physical medicine—and to direct the benefits of this branch of medicine to the rehabilitation of persons maimed in war, industry, or by illness—Bernard M. Baruch, in 1944, made an initial grant of $1,100,000 to the Baruch Committee on Physical Medicine.

The first annual report of the Committee, prepared by the Medical Director, Dr. Frank H. Krusen, of the Mayo Clinic, has outlined the progress in attaining the objectives of Mr. Baruch's endowment.

Eleven medical schools received funds from the original grants. The report shows the amount allocated to each school, and summarizes the activities of the year in the specific institutions,—such as the appointment of directors of the program and professors of physical medicine, creation of courses leading to a degree in occupational and physical therapy, equipment of new laboratories for research, and plans for research in varied fields of science.

NEW CATALOGUE OF UNITED STATES GOVERNMENT FILMS FOR SCHOOLS AND INDUSTRIES

This catalogue, just published, contains for the first time a complete list of all United States Government sound films (sixteen millimeter) and filmstrips (thirty-five millimeter). It includes 466 motion pictures and 432 filmstrips of the United States Office of Education, as well as training films and other types of educational film produced by the Navy, War Department, Department of Agriculture, and United States Public Health Service.

The library of films shows the completed production program of the Department of Visual Aids, United States Office of Education, and is the result of the cooperative efforts of many individuals. Twenty-three visual and technical specialists planned and supervised the productions, which were made by thirty-six motion-picture companies.

Films helped in a small measure to win the war, as training time was shortened and production was increased. Educators regard them as of the greatest use for peacetime teaching and training in schools and industry.

The catalogue may be obtained from Castle Films, Incorporated, distributors, 30 Rockefeller Plaza, New York, N. Y.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Thirteenth Annual Convention of The American Academy of Orthopaedic Surgeons was held at the Palmer House, Chicago, January 19, 20, 21, 22, and 23, 1946, under the presidency of Dr. E. Bishop Mumford, of Indianapolis. The first day was devoted to registration; the attendance was larger than at any previous meeting, with 1223 Fellows and guests registering. An excellent program of scientific motion pictures was presented on the first day and at definite periods throughout the meeting. Opportunity was given at various times to visit the many scientific and technical exhibits.

Instructional Courses, arranged by Dr. J. E. M. Thomson, were offered on the second day of the Convention, and the morning of the third day was devoted to a symposium on Degenerative Hip Disease. An Instructional Course dinner was given on the evening of January 19, followed by a panel discussion of The Painful Shoulder and Upper Extremity.

The following papers were read and discussed at the Scientific Sessions, on January 21, 22, and 23:

MONDAY, JANUARY 21

Afternoon Session

Spasmodic Torticollis: Severe Organic Type Treated by Combined Operation, Rhizotomy, and Fusion.
Dr. Alfred W. Adson, Rochester, Minnesota. (By invitation.)
Dr. H. Herman Young, Rochester, Minnesota.
Dr. Ralph K. Ghormley, Rochester, Minnesota.
Discussion: Dr. Loyal Davis, Chicago, Illinois. (By invitation.)
Dr. Lloyd T. Brown, Boston, Massachusetts.

Sympathetic Block of the Stellate Ganglion: Its Applications in Orthopaedic Conditions.
Dr. Guy A. Caldwell, New Orleans, Louisiana.
Dr. T. F. Broderick, Jr., Boston, Massachusetts. (By invitation.)
Dr. R. M. Rose, New Orleans, Louisiana. (By invitation.)
Discussion: Dr. J. E. M. Thomson, Lincoln, Nebraska.
Dr. Edward L. Compere, Chicago, Illinois.

The Operative Treatment of Scoliosis—A Corrective Appliance Supersedes the Bent Cast.
Dr. Walter P. Blount, Milwaukee, Wisconsin.
Dr. Albert C. Schmidt, Milwaukee, Wisconsin.
Discussion: Dr. Joseph S. Barr, Boston, Massachusetts.
Dr. H. R. McCarroll, St. Louis, Missouri.

The Multiple Innervation of Limb Muscles in Man.
Dr. W. Henry Hollinshead, Durham, North Carolina. (By invitation.)
Dr. J. E. Markee, Durham, North Carolina. (By invitation.)
Discussion: Dr. Eben J. Carey, Milwaukee, Wisconsin.
Dr. R. Plato Schwartz, Rochester, New York.

Knee Fusion by Three-Flanged Nail.
Dr. David M. Bosworth, New York, N. Y.
Discussion: Dr. Allen F. Voshell, Baltimore, Maryland.
Dr. E. W. Ryerson, Chicago, Illinois.

TUESDAY, JANUARY 22

Morning Session

Plastic Operations on the Hip with Special Reference to Results from Arthroplasty with Cups of Methyl Methacrylate.
Dr. Paul H. Harmon, Milton, West Virginia.
Discussion: Dr. Lenox D. Baker, Durham, North Carolina.
Dr. M. N. Smith-Petersen, Boston, Massachusetts.

Experiences with the Brittain Ischiofemoral Arthrodesis.
Dr. Joseph A. Freiberg, Cincinnati, Ohio.
Discussion: Dr. Carl C. Chatterton, St. Paul, Minnesota.
Dr. Robert A. Knight, Memphis, Tennessee.
Dr. David M. Bosworth, New York, N. Y.

Treatment of Congenital Dislocation of the Hip.
Dr. Edward L. Compere, Chicago, Illinois.
Dr. William J. Schnute, Chicago, Illinois. (By invitation.)
Discussion: Dr. H. R. McCarroll, St. Louis, Missouri.
Dr. E. W. Ryerson, Chicago, Illinois.

Mobilization of Metacarpophalangeal Joints—Capsulotomy and Arthroplasty.
Captain Samuel B. Fowler, M.C., A.U.S. (By invitation.)
Discussion: Dr. Sterling Bunnell, San Francisco, California.
Dr. J. S. Speed, Memphis, Tennessee.

Psychological Problems Observed in Military Orthopaedic Surgery.
Major J. Vernon Luck, M.C., A.U.S.
Discussion: Dr. Alan DeForest Smith, New York, N. Y.
Dr. Arthur Steindler, Iowa City, Iowa.

Factors Influencing Callus Formation in Open Fixation of Fractures.
Dr. Jean Verbrugge, Antwerp, Belgium. (By invitation.)

Progress Report of the Joint Committee on Postgraduate Training in Orthopaedic Surgery.
Dr. Ralph K. Ghormley, Rochester, Minnesota, *Chairman.*

Afternoon Session

Treatment of Compound, Comminuted Fractures Involving the Elbow Joint by Resection of the Fragments.
Dr. J. T. Nicholson, Philadelphia, Pennsylvania.
Discussion: Dr. Jean Verbrugge, Antwerp, Belgium. (By invitation.)

Restoration of Bone Strength with Reinforcement Bone Grafts.
Dr. George K. Carpenter, Nashville, Tennessee.
Dr. Robert T. Rosenfeld, Highland Park, Illinois. (By invitation.)
Major Karl F. Mech, M.C., A.U.S.
Discussion: Dr. W. W. Plummer, Buffalo, New York.
Colonel Robert H. Kennedy, M.C., A.U.S.

Reconstruction of Defects of the Tibia and Femur with Apposing Massive Grafts from the Affected Bone. A Preliminary Report.
Major John J. Flanagan, M.C., A.U.S.
Captain Henry S. Burem, M.C., A.U.S. (By invitation.)
Discussion: Dr. J. S. Speed, Memphis, Tennessee.
Dr. James A. Dickson, Cleveland, Ohio.

Skin-Grafting in the Treatment of Osteomyelitis.
Lt. Colonel Robert P. Kelly, M.C., A.U.S. (By invitation.)
Discussion: Dr. Ralph K. Ghormley, Rochester, Minnesota.
Colonel Leonard T. Peterson, M.C., U. S. Army.

The Overseas Treatment of Compound Fractures of the Long Bones.
Dr. George O. Eaton, Baltimore, Maryland.
Discussion: Dr. Edwin F. Cave, Boston, Massachusetts.
Dr. W. H. McGaw, Cleveland, Ohio.

WEDNESDAY, JANUARY 23

Morning Session

Neurectomy to Produce Atrophy of Amputation Stump.
Dr. Alfred O. Adams, Spokane, Washington.
Discussion: Lt. Colonel Clinton L. Compere, M.C., A.U.S.

Conservation of Short Amputation Stumps by Utilization of Tendon Section.
Lt. Colonel Harry C. Blair, M.C., A.U.S.
Major Harry D. Morris, M.C., A.U.S.

The Technique of the Syme Amputation.
Major R. H. Alldredge, M.C., A.U.S.
Lt. Colonel T. C. Thompson, M.C., A.U.S.
Discussion: Major Harry C. Morris, M.C., A.U.S.
Dr. William E. Gallie, Toronto, Ontario, Canada.

A Five-Point Plan for the Rehabilitation of the Arm Amputee.
Captain H. H. Kessler, M.C., U.S.N.R.
Discussion: Dr. Harold Conn, Akron, Ohio.
Lt. Colonel Ernest E. Myers, M.C., A.U.S.

Afternoon Session

Disability Evaluation for the Hand.
Major Donald B. Slocum, M.C., A.U.S.

Captain Donald R. Pratt, M.C., A.U.S.
Discussion: Major L. D. Howard, M.C., A.U.S.
Dr. Earl D. McBride, Oklahoma City, Oklahoma.

The Use of Cellophane in Reconstructive Orthopaedic Surgery.
Dr. Duncan C. McKeever, Houston, Texas.
Discussion: Major Louis W. Breck, M.C., A.U.S.
Dr. Philip Lewin, Chicago, Illinois.

Transplantation of Tendons through Preformed Gliding Channels.
Major J. E. Milgram, M.C., A.U.S.
Discussion: Dr. Robert D. Schrock, Omaha, Nebraska.
Dr. Leo Mayer, New York, N. Y.

The Repair of Knee Ligaments by Cutis-Graft Transplants.
Dr. Randolph L. Anderson, Charleston, West Virginia.
Discussion: Dr. H. Page Mauck, Richmond, Virginia.
Dr. Emil D. W. Hauser, Chicago, Illinois.

Semidelayed Bone Graft for Subcapital Fractures of the Hip.
Dr. Arch F. O'Donoghue, Sioux City, Iowa.
Dr. Edmund S. Donohue, Sioux City, Iowa. (By invitation.)
Discussion: Dr. Walter P. Blount, Milwaukee, Wisconsin.
Dr. Austin T. Moore, Columbia, South Carolina.

The Annual Dinner, at which President Mumford presided and delivered his Presidential Address, was held Tuesday evening, January 22. Part of the program for the evening consisted of the announcement of the scientific exhibits meriting awards and certificates, as follows:

Gold-Medal Awards

For Originality of Presentation; to the Medical Officers of Camp Carson, Colorado; Title of exhibit, "Trench Foot".

For Scientific Value; to Dr. John Lyford, III, and Dr. Robert W. Johnson, Jr., Baltimore, Maryland; Title of exhibit, "Granuloma Inguinale as a Cause of Arthritis and Osteomyelitis".

For Clinical Value; to Dr. Charles J. Basile, Dr. William L. Waldrop, Dr. Allen F. Voshell, and Dr. Moses Gellman, Baltimore, Maryland; Title of exhibit, "Subtalar Arthrorisis for Certain Types of Flat-Foot".

Honorable Mention

For Originality of Presentation; to Dr. H. H. Young and Dr. Ralph K. Ghormley, Rochester, Minnesota; Title of exhibit, "Injuries Due to Farm Accidents".

For Scientific Value; to Major J. E. Milgram, M.C., A.U.S.; Title of exhibit, "Operative Creation of New Gliding Channels for Muscle Bellies and Tendons".

For Clinical Value; to Commander Edward H. Crosby, M.C., U.S.N.R.; Title of exhibit, "A New Surgical Procedure for Repair of Recurrent Dislocation of the Shoulder".

Honorable Mention for "Gadgets and New Ideas"

To Dr. George Dawson, Florence, South Carolina, for his "Motor-Driven Screw-Holder-Screw-Driver".

To Dr. J. Warren White, Greenville, South Carolina, for his "Shelf-Bracket Well-Leg Traction".

To Dr. Robert T. Schrock, Omaha, Nebraska, for his "Skeletal Neck Brace".

To Dr. G. Mosser Taylor and Dr. Alonzo J. Neufeld, Los Angeles, California, for their "Femoral Nail Plate", "Special Retractor for Spinal Surgery", and "Method of Inserting Skeletal Traction to the Fingers".

Newly elected Fellows presented at the Meeting were:

Dr. John Hamilton Allan, Philadelphia, Pennsylvania
Dr. George Guy Bailey, Boston, Massachusetts
Dr. Dorsey K. Barnes, Dallas, Texas
Dr. Henry Hilliard Beckering, Dallas, Texas
Dr. Carl Berg, Washington, D. C.
Dr. William Harold Bickel, Rochester, Minnesota
Dr. John Robert Black, Los Angeles, California
Dr. Arthur Irving Blieden, New York, N. Y.
Dr. F. Bert Brown, Savannah, Georgia

Dr. Theodore Waggoner Bywaters, Dallas, Texas
Dr. Gene D. Caldwell, Shreveport, Louisiana
Dr. Lewis N. Cozen, Los Angeles, California
Dr. Burr Harding Curtis, Hartford, Connecticut
Dr. George Robert Dawson, Jr., Florence, South Carolina
Dr. Ernst Dehne, Wilmette, Illinois
Dr. George Lane Dixon, Tucson, Arizona
Dr. Francis Harold Downing, Fresno, California
Dr. Louis Henry Edmunds, Seattle, Washington
Dr. Norton Sheldon Freedman, Hato Rey, Puerto Rico
Dr. Charles W. Goff, Hartford, Connecticut
Dr. Malcolm B. Hadden, Berkeley, California
Dr. A. Scott Hamilton, Monroe, Louisiana
Dr. Clement Richard Hanlon, Bethlehem, Pennsylvania
Dr. S. Sverre Houkom, Duluth, Minnesota
Dr. Robert Tasker Humphries, Clarksburg, West Virginia
Dr. Lewis L. Huston, Longmeadow, Massachusetts
Dr. John B. Kelley, Worcester, Massachusetts
Dr. Robert Allen Knight, Memphis, Tennessee
Dr. Lawrence Robert Leidig, Santa Monica, California
Dr. Paul Rogers Lipscomb, Rochester, Minnesota
Dr. James Lytton-Smith, Phoenix, Arizona
Dr. John Laing McDonald, Toronto, Ontario, Canada
Dr. Robert Talbot McElvenny, Chicago, Illinois
Dr. Paul B. Magnuson, Chicago, Illinois
Dr. Eugene James Morrissey, Bethlehem, Pennsylvania
Dr. Robert M. O'Brien, St. Louis, Missouri
Dr. Robert Thornton Percival, Forest Hills, New York
Dr. Thomas H. Peterson, Boston, Massachusetts
Dr. Robert R. Rix, Manchester, New Hampshire
Dr. Peter-Cyrus L. Rizzo, Cambridge, Ohio
Dr. Harold H. Sankey, Pittsburgh, Pennsylvania
Dr. L. Stanley Sell, Oklahoma City, Oklahoma
Dr. Mario E. Stella, New York, N. Y.
Dr. Clyde Beverly Trees, Dallas, Texas
Dr. Harold Unger, Kansas City, Missouri
Dr. Frederick H. Vom Saal, New York, N. Y.
Dr. Richey L. Waugh, Boston, Massachusetts
Dr. Herman Leslie Wenger, New York, N. Y.

Dr. Jean Verbrugge, of Antwerp, Belgium, was elected Corresponding Member.

The First Executive Session was held at noon on Monday. At the Second Executive Session, held at noon on Wednesday, new officers and committee members for the year were elected.

The new officers of The Academy are:

President: Dr. J. E. M. Thomson, Lincoln, Nebraska
President-Elect: Dr. Rex L. Diveley, Kansas City, Missouri
Vice-President: Dr. Mather Cleveland, New York, N. Y.
Secretary: Dr. Myron O. Henry, Minneapolis, Minnesota
Treasurer: Dr. Fremont A. Chandler, Chicago, Illinois
Librarian-Historian: Dr. Edward L. Compere, Chicago, Illinois

The Fourteenth Annual Convention will be held in Chicago, in January 1947.

Current Literature

Extensile Exposure Applied to Limb Surgery. Arnold K. Henry, M.B., Dublin; M.Ch. (Hon.), Cairo; F.R.C.S.I. Edinburgh, E. and S. Livingstone Ltd.; Baltimore, The Williams and Wilkins Company, 1945. $7.00.

In this book of 180 pages, illustrated with skill and care, Henry not only describes the surgical exposures by which extremity operations may be performed, but elucidates the philosophy underlying physiological dissection by the surgeon in reaching a given region. In addition, the approaches are so conceived that they may readily be extended (hence "extensile"), while at the same time there is maximum (and adequate) provision for safety against inadvertent surgical damage to important structures. The approaches, conceived with originality and a perspective based on profound knowledge of anatomy, are of proven worth, and appear in book form after modification under the stress of use in many lands by many surgeons with varying degrees of skill and experience.

Some of the approaches the author has described in a previous book, long a classic, (Exposures of Long Bones and Other Surgical Methods, New York, William Wood and Company, 1927). Valuable as is the earlier work, the present volume is so much more lucid that it is in truth a new and different book.

The work can scarcely be recommended too highly. It is hard to see how one can do the best orthopaedic operating without a knowledge of its contents.

Hey Groves' Synopsis of Surgery. Edited by Cecil P. G. Wakeley, C.B., D.Sc., F.R.C.S., F.R.S.E., F.A.C.S., F.R.A.C.S. Ed. 12. Bristol, John Wright & Sons, Ltd.; Baltimore, The Williams and Wilkins Company, 1945. $6.00.

In 1908 the great British surgeon, Ernest W. Hey Groves, edited "Synopsis of Surgery". In the preface to the first edition, he wrote:

"The present volume is an attempt to make an epitome of the salient facts in surgical practice, and to place these facts in such a manner that they may most easily and rapidly be referred to or revised. It has been compiled almost entirely from notes made by the author in preparing students for examinations.

"It is of course obvious that the large works cannot be dispensed with; but after a student has carefully read through a complete text-book, which ought to be done at the time he is actually engaged in ward and out-patient work, he may find this Synopsis an aid to his memory in retaining a vast array of facts in an orderly manner."

Not only the student, but also the busy practitioner has found this Synopsis a compendium of knowledge of surgical diagnosis and treatment and of practical value because of its concise form and methodical arrangement.

Periodically, the Synopsis has been thoroughly revised; the twelfth edition was almost completed at the time of Mr. Hey Groves' death. The work was taken up and completed by his friend, Cecil P. G. Wakeley.

This edition represents a careful and thorough revision. The inclusion of penicillin and the sulfonamides has necessitated a complete rewriting of several chapters. Many new developments in surgical technique are presented in this latest edition.

It is to be hoped that new editions of the work will continue to appear from time to time.

Surgical Treatment of the Motor-Skeletal System. Frederic W. Bancroft, A.B., M.D., F.A.C.S., and Clay Ray Murray, M.D., F.A.C.S., Editors. Philadelphia, London, and Montreal, J. B. Lippincott Company, 1945. $20 a set (two volumes).

The broad subject of surgical treatment is dealt with in this two-volume publication from the point of view of presenting an up-to-date picture of operations involving the motor-skeletal system. The scope of the work is not limited to surgical technique, however, but includes a discussion of the indications for operation, the postoperative treatment, and the prognosis. Alternative operative procedures are described for certain conditions.

Part I deals with congenital and acquired deformities; paralytic disorders; affections of back, muscles, fasciae, tendons, bursae, and ganglia; new growths; diseases of bones and joints; and amputations. Part II includes fractures and dislocations; sprains, sprain-fractures, muscle and tendon injuries; birth injuries of the motor-skeletal system; and military surgery.

The work represents the combined efforts of forty-three authors, each of whom has contributed a chapter or section. If the statements of an author are incomplete or deal with controversial subjects, amplifications and comments are often interpolated by the editors. This author-editor relationship, in its collaborative effect, adds materially to the value of the work.

A short list of references follows each section, but the books are intended for general use rather than as reference volumes.

THE 1945 YEAR BOOK OF INDUSTRIAL AND ORTHOPEDIC SURGERY. Charles F. Painter, M.D., Editor. Chicago The Year Book Publishers, 1946. $3.00.

The value of a year book depends primarily upon the wisdom with which the material is selected The careful choice of articles on orthopaedic subjects by the Editor and the excellent abstracts of the articles combine to make this book of value, especially to those who have not been able to follow the current literature in the field. It gives a clear summary of the important developments during the year in the field of orthopaedic surgery.

The last section is devoted to a résumé of the literature on industrial medicine and surgery. In this section have been emphasized some of the health hazards introduced by war.

DR. W. C. RÖNTGEN. Otto Glasser, Ph.D. Springfield, Illinois, Charles C. Thomas, 1945. $4.50.

Under the combined sponsorship of the American Roentgen Ray Society, the Radiological Society of North America, and the American College of Radiology, this book appeared in 1945—which is both the hundredth anniversary of Röntgen's birth and the fiftieth anniversary of his discovery of roentgen rays—as a condensation of Dr. Glasser's comprehensive *Wilhelm Conrad Röntgen and The Early History of the Roentgen Rays*, published in 1934. The original work was developed by Dr. Glasser with the authority born of native understanding, education, and exhaustive care in preparation, as well as his unusual access to most important material. This smaller book is exceedingly readable; it consists of delightful biography, a chronological survey of Röntgen's life and achievements, the translation of his classic *Communications*, and some interesting new illustrations. Both professional and lay readers will find enjoyment and benefit in learning anew of this memorable man, one of the greatest physicists the world has known, who has done much to lighten the ills of the human race by helping to make the practice of medicine a science as well as an art.

MEN WITHOUT GUNS. DeWitt Mackenzie. Foreword by Major General Norman T. Kirk, M.C. Philadelphia and Toronto, The Blakiston Company, 1945. $5.00.

In "Men Without Guns" are grouped more than a hundred reproductions of paintings by twelve distinguished artists who were assigned to different theaters of the War. Their purpose was to give to people at home an account of how the health of their boys in various zones of conflict was being safeguarded and of how the wounded were cared for.

The paintings they produced did more than that; they were a record of the work of the Army Medical Department in many lands. They are not in any sense a history of Army medicine, but rather the artists' impressions of what they saw under all conditions of war. They pay high tribute to the corpsman and to the Army nurse, as well as to the doctors in all links of the chain of the Army program, from the battalion aid station through the clearing station, the evacuation hospital, the general hospital, the embarkation hospital, hospital plane or hospital ship, the debarkation hospital, and finally the general hospital at home.

The text is an interesting account of experiences on the different fronts—the Southwest Pacific, Italy, Normandy, and Burma. It is written for the layman, not the medical man. However, the book will be remembered primarily for the reproductions of great paintings, which faithfully portray the work of the Medical Corps.

In his foreword, Surgeon General Norman T. Kirk said: "No artist ever had a more worthy subject for his brush than did the twelve distinguished painters whose canvases on Army Medicine are reproduced in this volume.

"Unequivocally and without fear of contradiction, I say with pride and reverence that one of the greatest contributions to victory has been made by the doctors, nurses, and enlisted men of the Army Medical Department. Without their tireless devotion to duty, their courage and complete disregard for self-safety, the Medical Department would not be able to point today to a record of achievement unmatched in the long history of warfare."

END-RESULTS IN THE TREATMENT OF HYPERPARATHYROIDISM. Roy D. McClure and Conrad R. Lam. *Annals of Surgery*, **121**: 454–469, 1945.

In this small series are examples of all clinical types of hyperparathyroidism: classic von Recklinghausen's disease; osteoporosis, with and without renal stones; renal stones alone; and a type which has been called acute parathyroid poisoning. Only one of the six patients did not have surgical treatment, and he died with acute parathyroid intoxication. Adenomata were removed from the other five patients. One died four months later in an hypoparathyroid state. The four remaining patients have now been followed for periods ranging from four to eight years, and they appear to be normal.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

INTERVERTEBRAL DISK LESIONS ARE THE MOST COMMON CAUSE OF LOW BACK PAIN WITH OR WITHOUT SCIATICA. J. Albert Key. *Annals of Surgery*, **121**: 534–544, 1945.

With customary forthrightness, the author sets forth the thesis that "The conditions which we have called low back strains and classified as idiopathic low back pain are lesions of the intervertebral disks

in this area." It is pointed out that the operative cure of disc lesions is an elective major surgical procedure which should not be undertaken lightly. Instead, it must be recognized that the surgeon's duty is to relieve the patient's symptoms in the simplest and safest manner. If conservative means fail, the surgeon can resort to operative removal of the disc with reasonable assurance of success.

The article is provocative and controversial, but it clearly sets forth the present views of a competent surgeon concerning a subject of great clinical importance.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

QUADRICEPSPLASTY. T. Campbell Thompson. *Annals of Surgery*, 121: 751–755, 1945.

This procedure rests upon the sound basis that the function of a tendon depends upon the absence of scarring between the tendon and the surrounding structures. In the operation to restore flexion to the knee, the joint is forcibly flexed to 90 degrees without lengthening the rectus femoris muscle. If either of the vastus muscles is badly scarred, it is isolated and removed from the rectus by making a new intermuscular septum of soft tissues. The intact rectus femoris permits early motion and an early resumption of full, active extension. In selected cases, this procedure has certain advantages over Bennett's original operation for quadriceps lengthening.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

BONE SARCOMA IN POLYOSTOTIC FIBROUS DYSPLASIA. Bradley L. Coley and Fred W. Stewart. *Annals of Surgery*, 121: 872–881, 1945.

So far as is known, this is the first report of the occurrence of malignant disease resulting from fibrous dysplasia of bone. Since this syndrome is being recognized with increasing frequency, the possibility of the late appearance of bone sarcoma is important. It is concluded on the basis of two carefully observed cases that polyostotic fibrous dysplasia is one of a group of bone diseases in which malignant tumors occasionally develop. The histological appearance was identical, the pattern was non-bone-forming pleomorphic spindle-cell and giant-cell tumors. Metastases were apparently produced in both cases. The response to radiotherapy was marked by unusual and unexpected relief from pain and by some evidence of bone regeneration.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

TRAUMATIC OSTEOMYELITIS. THE USE OF SKIN GRAFTS—PART I. TECHNIC AND RESULTS. Robert P. Kelly, Louis M. Rosati, and Robert A. Murray. *Annals of Surgery*, 122: 1–11, 1945.

These authors report on the satisfactory use of skin-grafting in the treatment of osteomyelitis. The technique is fully described. Emphasis is given to the need for a thorough preliminary saucerization and the equal need for applying the grafts so that compression can be distributed evenly to all of them. On the basis of approximately 100 cases treated by the method described, it is believed that this is a safe form of treatment and that it will give beneficial results in the majority of instances. While occasional reports of the successful use of skin grafts in the treatment of osteomyelitis have appeared in the literature for many years, the method has not received wide use. The authors hope that this encouraging report will stimulate others to apply this treatment.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

MONO-ARTICULAR OSTEO-ARTHRITIS OF THE HIP. TREATMENT BY ACID INJECTION. W. Grant Waugh. *British Medical Journal*, 1: 873–874, 1945.

Over a nine-year period, the author has employed intra-articular acid injection in the treatment of over 1,200 cases of various types of arthritis, including osteo-arthritis, traumatic arthritis, "menopausal" arthritis, and rheumatoid arthritis in the stage of residual deformity, with the idea of reducing alkalinity of the synovial fluid. Although statistics are lacking, he estimates that over 70 per cent of the patients have been relieved of pain and have sufficient restoration of function to permit normal occupation.

He tried the same form of treatment in cases of mono-articular arthritis of the hip joint, which had previously proved resistant to most forms of therapy. Of 142 cases examined by the author, 108 have been treated by weekly injections into the joint of from 15 to 20 cubic centimeters of a solution of lactic acid (pH 5.8), together with procaine. This was followed by gradual manipulation and exercises, without weight-bearing. Follow-up results were obtained in only twenty-six of the patients; of this group, between 50 and 60 per cent are able to carry on their normal occupations.

Loss of joint space, indicating extreme destruction of the articular cartilage, is the chief contra-indication to this form of treatment.

NYLON BONE SUTURE. M. John Rowe. *Surgery*, 18: 764–768, 1945.

Nylon is a strong, inert, semi-elastic, non-organic, radiolucent suture material which has been found to be well tolerated by the tissues. Rowe reports satisfactory results with the use of nylon bone sutures. These sutures have been used successfully in the repair of acromioclavicular separations, hallux valgus, and fractured patellae; as intertarsal sutures following reconstruction operations; and in the maintenance of position of loose fragments in compound fractures of the long bones.—*Edward L. Compere, M.D., Chicago, Illinois.*

Roentgenographic Interpretation of What Constitutes Adequate Reduction of Femoral Neck Fractures. Robert T. McElvenny. *Surgery, Gynecology, and Obstetrics,* **80**: 97–106, 1945.

The author has evaluated from his own experience various ways of dealing with intracapsular fractures of the hip. Certain facts have been obtained from his study of failures, and these facts are used in formulating criteria of roentgenographic interpretation at the time of reduction and nailing of fractures. All failures have occurred in hips which have been reduced imperfectly,—that is, the neck fragment has not been placed well under and well inside the head fragment. McElvenny feels that accurate placement is absolutely necessary in order that fixation may act as a guide to allow the head to settle on the neck in a position in which the weight thrust is applied directly to the fracture site, without shearing or torsion forces being exerted on the fixation material.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

Rapid Repair of Defect of Femur by Massive Bone Grafts after Resection for Tumors. Dallas B. Phemister. *Surgery, Gynecology, and Obstetrics,* **80**: 120–127, 1945.

By means of bone-grafting, amputation was avoided in two cases of locally resected bone tumors of the lower end of the femur. Two tibial grafts, each between two-fifths and one-half the circumference of the shaft and from seven to eleven inches in length, were used to bridge the defect. The grafts were part onlay and part intramedullary, with fixation by threaded wires at each end. Firm bony union was obtained in about twelve weeks in one case and in five months in the other case. At the end of three and one-half years, both grafts had been transformed into tubular bone.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

Aseptic Necrosis of the Capital Femoral Epiphysis Following Adolescent Epiphyseolysis. Robert D. Moore. *Surgery, Gynecology, and Obstetrics,* **80**: 199–204, 1945.

Moore reviews the literature dealing with descriptions of femoral epiphyseal pathological lesions and gives a detailed account of the macroscopic and microscopic findings in two cases of slipped femoral epiphysis. The article is a purely descriptive recording and offers no new explanation as to cause.

This paper may be summarized briefly, as follows: After interruption of the blood supply to the epiphysis in adolescents, the overlying articular cartilage may remain viable or may undergo partial or complete necrosis. In either case, subsequent degenerative and reparative changes apparently result in reduction of the depth of the articular cartilage, as occurs in the adult with aseptic necrosis of the head, following fracture of the neck of the femur. This is in contrast to the changes seen in Legg-Perthes disease, where rapid growth of the living articular cartilage compensates for any absorption or ossification of the cartilage which takes place after revascularization of the ossification center. Under these circumstances, the depth of the articular cartilage usually increases.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

The Journal wishes to acknowledge receipt of the following publications, which were sent to the Editorial Department:

Anais Paulistas de Medicina e Cirurgia (São Paulo, Brasil), **50**: Nos. 3, 4, 5, e 6, 1945.
Analecta Medica (México), **6**: No. 3, 1945.
The Bethesdan (Cincinnati, Ohio), **46**: No. 4, 1945.
Boletím do Sanatório São Lucas (São Paulo, Brasil), **7**: Nos. 3, 4, 5, e 6, 1945.
Boletín del Colegio Médico de la Habana (Cuba), **8**: Núm. 12, 1945; **9**: Núm. 1, 1946.
The Bulletin of the U. S. Army Medical Department (Carlisle Barracks, Pennsylvania), **5**: Nos. 1 and 2, 1946.
Harper Hospital Bulletin (Detroit, Michigan), **3**: No. 3, 1945.
Médica (Matanzas, Cuba), **4**: Núm. 6, 1945.
The National Foundation for Infantile Paralysis (New York, N. Y.), National Foundation News, **5**: No. 1, 1946.
The Physiotherapy Review (New York, N. Y.), **25**: No. 6, 1945; **26**: No. 1, 1946.
Radiography and Clinical Photography (Rochester, N. Y.), **21**: No. 3, 1945.
Revista Médica Municipal (Rio de Janeiro, Brasil), **6**: Núm. 2, 1945.
Sanidad y Beneficencia Municipal (Habana, Cuba), **5**: Núm. 2, 1945.
Santa Casa de Misericordia de Itatiba (Brasil), Relatorio da Diretoria, 1944.
Sociedad de Cirurgía de Córdoba (Argentina), Boletines y Trabajos, **6**: Nos. 5 y 6, 1945.
United States Public Health Service (Washington, D. C.), Public Health Bulletin No. 291: "A Medical Study of the Effect of TNT on Workers in a Bomb and Shell Loading Plant" and "Report of Fatal Case of Aplastic Anemia"; The Journal of Venereal Disease Information, **26**: No. 12, 1945; **27**: Nos. 1 and 2, 1946; Public Health Reports, **60**: Nos. 51 and 52, 1945; **61**: Nos. 1 to 11, 1946; Supplements, Nos. 187, 188, and 189.

The Journal of
Bone and Joint Surgery

THE TECHNIQUE OF THE SYME AMPUTATION *

BY LIEUTENANT COLONEL RUFUS H. ALLDREDGE AND
LIEUTENANT COLONEL T. CAMPBELL THOMPSON

Medical Corps, Army of the United States

The merits of the Syme amputation, first described over a hundred years ago, have been debated more than those of any other major amputation. This operation, although well known, was not employed very widely in this country prior to World War II. Little use of it was made in World War I on American wounded, and there were very few good results. Although some American surgeons have recognized its value and have advocated it consistently, most of them have not made full use of it for various reasons, the most important of which has been fear of unsatisfactory end results.

The Syme amputation was employed rather extensively by the British and Canadians in World War I. The follow-up on the British cases at the Amputation Center of the Ministry of Pensions at Roehampton, England, has shown the results to be so unfavorable that the surgeons and limb-fitting surgeons there have condemned the operation completely. They have stated that the chief cause of failure was imperfect stumps, which resulted from surgery done in the presence of, or too soon after, sepsis.

Among the Canadians, on the other hand, many good Syme amputations were done in World War I; and many Canadian surgeons strongly advocate the operation, whenever it is indicated.

At the beginning of World War II, the authors had had very little experience with the Syme amputation, but soon began performing it on carefully selected patients, wounded in the War. The immediate results were so encouraging that the operation was soon performed without hesitation in any case in which it was definitely indicated. Seventy-five Syme amputations have now been performed by the authors during the past three years in the Army. The fundamentals of the technique described here have been followed on all cases from the beginning; but minor changes and improvements have been made from time to time, until the operative technique now used has been developed. Because the proper selection of cases and the after-care are just as important as the operative technique and have such important bearing on the results, these phases are also discussed.

The purpose of this paper is to present the methods employed and the technique found to be useful in obtaining satisfactory results in a very high percentage of Syme amputations.

ADVANTAGES

The Syme amputation has definite advantages over amputations below the knee and over most short foot amputations, which often produce poor functional results. The Syme

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 23, 1946.

method is far more conservative and the limb is better functionally than with an amputation below the knee. Patients having good Syme amputations are truly appreciative of the conservatism elected for them, and no case is known in which the patient would prefer to have had any other type of amputation. The Syme operation offers the best major amputation of the lower extremity in that the longer stump gives better leverage; and it is capable of full end-bearing, with or without a prosthesis. This factor is definitely of value in walking about the house. Psychologically, the Syme amputation is preferable to amputation below the knee, because the patient considers himself merely inconvenienced and not really handicapped. In bilateral amputation of the lower limb, a double Syme amputation is far preferable to a double below-the-knee amputation, because the patient can walk with a better gait and can stand longer. The Syme prosthesis does not extend above the knee; hence there is no necessity for a pelvic belt for suspension of the limb. If a double Syme amputation is impossible, one is always highly desirable in combination with an amputation below or above the knee, because the patient can protect the stump which is not end-bearing from too much use by relying primarily on the extremity with the Syme amputation for locomotion and prolonged standing. The authors have had personal experience with eight patients, each of whom had a Syme amputation on one side and a below-the-knee amputation on the other side; all prefer the Syme amputation to the below-the-knee type. Some of these patients have worn their prostheses for over a year. Patients in a large Amputation Center, where good results from the Syme operations are plentiful, prefer the Syme amputation to the below-the-knee type, as well as to most short amputations of the foot. Contrary to the generally accepted view, the Syme stump is simpler to fit with a prosthesis than a below-the-knee stump, and the prosthesis does not require as many adjustments after it has been fitted. The reason for this is that the Syme stump is fully end-bearing, and the socket does not have to be fitted as accurately to transmit the body weight through the soft skin of the leg as in the average below-the-knee prosthesis.

The Syme amputation also has many advantages over amputations through the foot, which are too short for good function. When the metatarsals have been lost, the body weight has to be borne by the heel and what is left of the fore part of the foot. Frequently there is muscle imbalance, which results in the strong and improperly opposed group of calf muscles pulling the foot into fixed equinus. This lifts the heel and lowers the end of the foot stump so that the heel no longer takes its share of the weight, while the end of the foot stump (which is often scarred) is forced to take more than its share of weight. This results in weight-bearing on one small point on the end of the stump, which becomes calloused and later breaks down. If the end of the stump happens to be scarred, it breaks down without callus formation.

In the Syme amputation the normal tough plantar skin of the heel is brought forward directly beneath the end of the tibia, where the weight of the entire body is transmitted into the socket of the prosthesis, without any friction against scarred areas. The Syme prosthesis is simpler to fit than any prosthesis which has yet been developed for the Chopart type of amputation. Patients who have had a Syme amputation have a better gait and far less pain and discomfort than patients with poorly functioning short foot stumps. The stump resulting from the Syme amputation is preferable to any short foot stump, which cannot be made, by surgery and proper fitting, to provide good function from the standpoint of locomotion and weight-bearing. The Syme amputation is the only amputation recommended at the ankle joint, and is preferable to any of its modifications, including the Pirogoff amputation.

DISADVANTAGES

It is unfortunate that, where amputations of the lower extremity are necessary, the Syme amputation cannot be used oftener. Approximately 2 per cent. of American Army

amputees from World War II have had the Syme amputation. This percentage seems low, but it is greater than that for several other sites of amputation,—such as the hip, knee, wrist, elbow, and shoulder joints. The low percentage of Syme amputations should in no way minimize the value and importance of the operation, as the number will increase with more widespread recognition of its merits.

The Syme amputation requires greater skill on the part of the surgeon in the proper selection of cases, the operative technique, and the postoperative care than any other amputation. The results, however, improve with the experience of the surgeon. Generally speaking, the Syme amputation requires a longer period from operation to limb-fitting than the below-the-knee amputation, but frequently the stump is ready for final fitting just as early as a below-the-knee stump. The bulbous ankle has often been criticized; but, in the authors' experience, men do not mind this, although it may be objectionable to young women. Unless the results from the Syme amputation are good—that is, the stump is capable of full end-bearing, it is well healed, has a minimum of scar, and is not tender or painful—amputation below the knee is preferable.

CONTRA-INDICATIONS

The Syme amputation should never be employed as a primary procedure after war injuries or in cases where the surgeon cannot properly supervise the postoperative care. If open wounds have been present—particularly an open amputation of the foot, as in war casualties—the operation should not be performed until the wounds are either clean or healed. Complete preoperative wound healing is not necessary for good results in experienced hands, but it is usually desirable and may be attained early by temporary skin-grafting. In the presence of open wounds, the operation should not be done until the cultures are sterile. The Syme amputation should not be performed, after the ligation of the major vessels, until sufficient time has elapsed for good collateral circulation to develop.

The Syme amputation should never be performed upon diabetic patients nor in the presence of peripheral vascular diseases, such as thrombo-angiitis obliterans or arteriosclerosis. Spina bifida and loss of sensation in the heel from injury or disease of the peripheral or central nervous system constitute clear contra-indications. The amputation should be performed only in cases in which there is enough plantar skin, with a good nerve and blood supply beneath the heel, to provide a weight-bearing covering over the cut ends of the tibia and fibula.

INDICATIONS

The Syme amputation is always preferable to amputation at a higher level, if done under the proper circumstances and if not contra-indicated in the individual case. Its greatest field of usefulness is in young men, who are otherwise in good general physical and mental condition, but who have suffered the traumatic loss of the greater part of the foot, so that the remaining stump cannot be made satisfactory for weight-bearing and locomotion either by surgery or by proper limb-fitting. Where there has been partial loss of the foot, together with a compound fracture or extensive loss of skin and soft tissue in the upper third of the leg, it is impossible to get a good below-the-knee stump; and in such a case amputation above the knee is the only alternative to the Syme amputation. These leg wounds may be treated as though the foot had not been lost, and the Syme amputation can be performed after the wounds have healed. Severe fractures in the region of the ankle and the lower third of the tibia and fibula are not uncommon in patients who have also lost most of the foot. Here, too, the fractures are treated until there is solid union; after this the Syme amputation may be performed, without regard to the presence of the fracture. Shortening of the limb from fractures above or below the knee can usually be disregarded, as the length can easily be compensated for in the fitting of the prosthesis. A

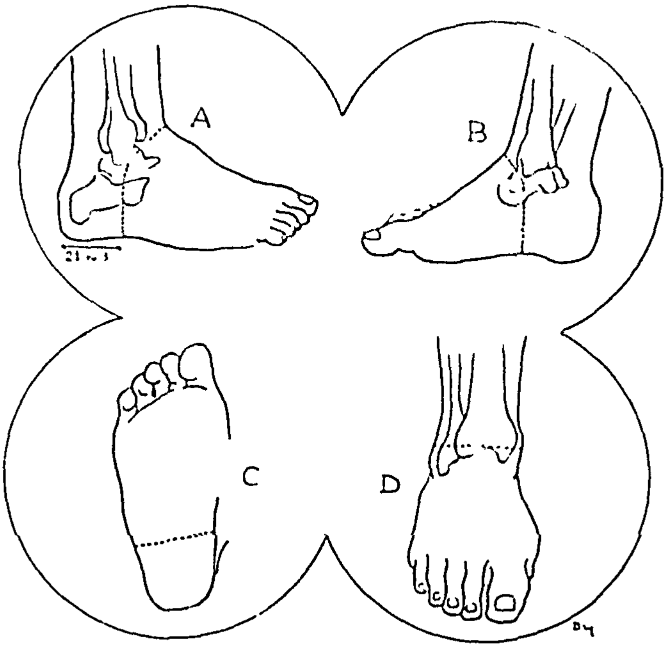

FIG. 1

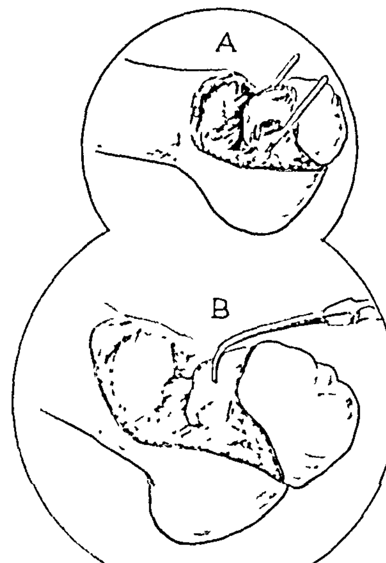

FIG. 2

Fig. 1: The line of incision for the Syme amputation.

Fig. 2: *A*: All soft-tissue structures are divided in the line of the skin incision, down to the bone. The ankle is dislocated forward by cutting the talofibular and calcaneofibular ligaments from the inside of each malleolus. *B*: In short foot stumps the bone hook is then inserted into the talus to facilitate pulling the parts forward, while the calcaneus is dissected extraperiosteally out of the heel flap.

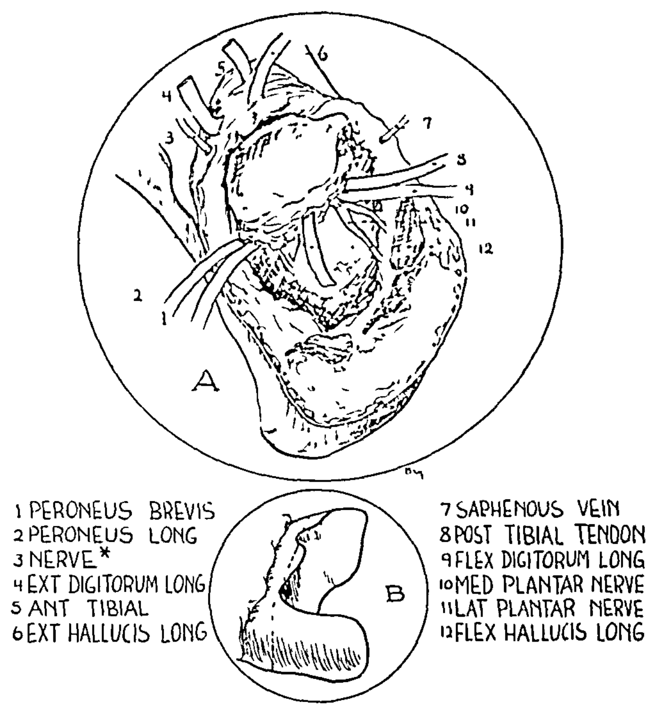

FIG. 3

Fig. 3: *A*: After the calcaneus has been dissected out extraperiosteally, the malleoli are exposed and sawed off. *B*: The saw line is placed as far distally as possible, and usually some of the articular cartilage on the end of the tibia is left. (See Fig. 4, *A*.)

* Superficial peroneal nerve.

good Syme amputation may be done if as little as one inch of good plantar skin is left on the heel. It may be performed for loss of the fore part of the foot, due to frostbite, trench foot, freezing, or any combination of these injuries, provided, first, that sufficient time has elapsed for the local circulation to be reestablished and, second, that persistent tenderness is not present in the soft-tissue covering of the heel, which is to be used for the end-bearing flap. It may also be used advantageously in certain cases of unilateral and bilateral congenital deformity, with marked shortening and disability.

PREOPERATIVE CARE

Proper selection of cases for the Syme amputation and judicious timing of the operation are the two most important preoperative considerations. When done after trauma, the extremity should be surgically and bacteriologically cleaner than for any other amputation. Temporary skin-grafting may shorten the period before operation, but is not always necessary. Roentgenograms should be taken in all cases, because unsuspected skeletal injuries frequently exist, particularly in war injuries. If oedema is present, it should be relieved by bed rest, elevation, wrapping, and, if necessary, by novocaine block of the sympathetic trunk. In patients

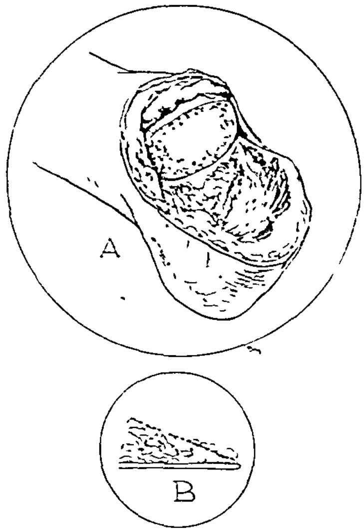

FIG. 4

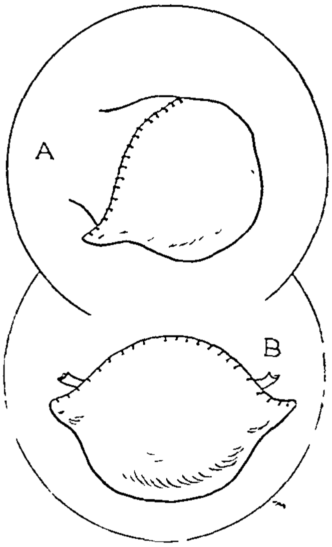

FIG. 5

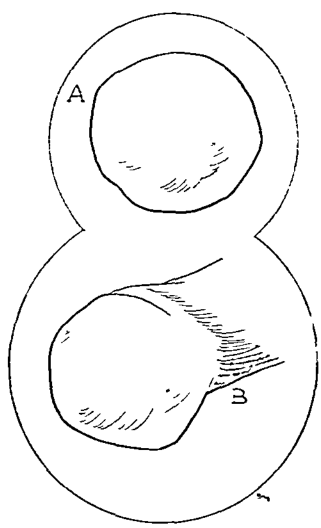

FIG. 6

Fig. 4: *A*: All tendons and nerves, except the tendo calcaneus, are pulled down, cut at the saw line, and allowed to retract proximally. The white island in the center of the end of the tibia represents cartilage. The heel flap is debrided and all muscle, fascia, periosteum, and loose devitalized strands of tissue are removed. *B*: The thick edge of the heel flap is trimmed; the sharp edge of the wedge faces anteriorly, for ease of closure. The tourniquet is then removed, and the remaining open vessels are clamped and ligated. Complete hemostasis is desirable.

Fig. 5: The heel flap is centered on the end of the leg and held there by an assistant, while the skin edges are approximated with interrupted sutures. No subcutaneous sutures are used. The stump is usually drained, as indicated in *B*, unless the foot has been clean and absolute hemostasis has been obtained. The lateral projections of skin, forming "ears", are never trimmed.

Fig. 6: Shows the contour of the stump after operation. Final forming and shaping are achieved by wrapping with elastic bandages (see Fig. 12).

who have had ligation of the major vessels or marked vasomotor spasm and have responded to novocaine block, lumbar sympathectomy should be done. Cultures should be taken on all open wounds, and operation should be postponed until the cultures are sterile. Patients should, of course, always have complete physical and laboratory examinations. The patient's mental status should be established before operation, since the best results can be obtained only when there is reasonably good cooperation on the part of the patient. Penicillin or chemotherapy should be used routinely in all cases which have, or have had, open wounds in the vicinity of the operative site.

OPERATIVE TECHNIQUE

The operation is performed in three major steps. The routine use of the pneumatic tourniquet above the knee is recommended. The operator stands at the end of the table, with an assistant on either side. After proper surgical preparation of the limb, it is rested on a block of wood about ten inches in height. For the purpose of description, the operative technique will be described as for a right-handed operator and a right leg.

Step 1

This consists of the skin incision, dislocation of the ankle, and removal of the calcaneus.

The incision is started across the front of the ankle joint on a line connecting the two most prominent points of the malleoli (Fig. 1). It extends medially to a point just in front of the medial malleolus (Fig. 1, *B*). From this point it is continued distally across the sole of the foot in a line at right angles to the long axis of the foot. From the lateral margin of the sole of the foot, it is continued proximally to the anterior margin of the lateral mal-

leolus. From this point, it is curved gently to meet the beginning of the incision (Figs. 1, *A* and 1, *C*). The distance from the posterior aspect of the heel to the line of incision on the sole of the foot will vary from two and one-half to three inches, depending upon the size of the leg and whether or not the foot is fixed in equinus. In patients with large ankles and feet and those having fixed equinus, the incision will extend farther forward on the sole of the foot. After the skin has been incised in this manner, all soft structures are divided in the line of the incision, down to the bone. This opens the ankle joint anteriorly so that the superior surface of the talus can be seen. The scalpel, with the sharp edge downward, is then placed in the joint space between the medial malleolus and the talus; and the deltoid ligament is divided, while the cutting edge of the scalpel is kept against the tarsal bones. The calcaneofibular ligament is divided in a similar manner (Fig. 2, *A*). This allows the talus to be dislocated forward so that a large bone hook can be inserted into its superior articular surface (Fig. 2, *B*). The hook is pulled forward with the left hand, while the surgeon very carefully removes the calcaneus extraperiosteally by sharp dissection with a scalpel. The sharp edge of the scalpel is always kept against the bone so that no damage will be done to the soft-tissue structures in the heel flap. When the tendo calcaneus has been reached, it is divided near its insertion into the calcaneus. The bone hook is then removed and inserted into the posterior part of the calcaneus to facilitate forward traction, while the remainder of the calcaneus is dissected out.

Step 2

This step consists of sawing off the malleoli, cutting tendons and nerves, debriding the heel flap, and ligating the major vessels.

By means of tissue forceps, the deep layer of subcutaneous fascia, just anterior to each malleolus, is identified and a subfascial extraperiosteal exposure of each malleolus is executed by sharp dissection; the exposure extends up to the level of the articular surface of the distal end of the tibia. Soft structures are retracted on either side of the ankle, and the malleoli are sawed off squarely in a plane at right angles to the long axis of the patient's body; the portion of the posterior aspect of the tibia which projects distally to the anterior

Fig. 7

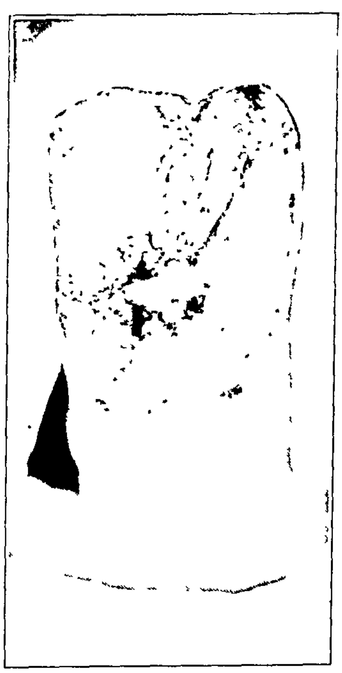

Fig. 8-A

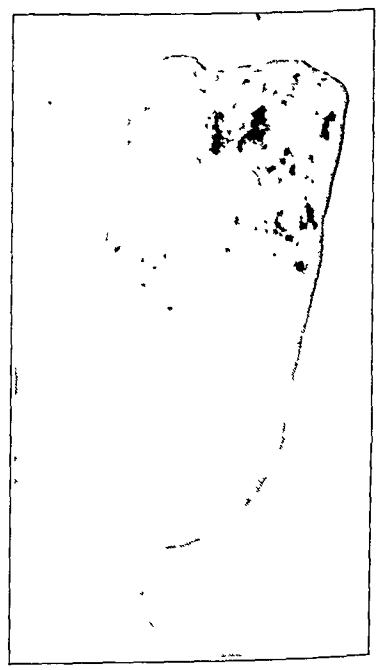

Fig. 8-B

Types of war wounds of the feet for which the Syme amputation is most commonly performed.

Fig. 7: The short Chopart stump is fixed in equinus and the end is covered by a wide scar.

Figs. 8-A and 8-B: Skin-grafting has been done. Grafts of this type are not satisfactory on weight-bearing areas.

FIG. 9-A FIG 9-B FIG. 9-C

Three views of a unilateral Syme stump, resulting from the technique described. (*Fig. 9-A is reproduced by courtesy of W. B. Saunders Company*[1].)

articular aspect is also sawed. The saw line is placed as far distally as possible, so that frequently a large area of articular cartilage may remain on the end of the tibia. The periosteum on the distal end of the tibia and fibula is left intact (Figs. 3 and 4).

Beginning with the tibialis anterior tendon and proceeding in a clockwise direction, all tendons and nerves except the tendo calcaneus are now isolated, clamped with Kocher clamps, pulled down, cut squarely off at the level of the saw line, and allowed to retract (Fig. 3). Great care must be exercised in handling the posterior branches of the tibial nerve, since it is so closely associated with the corresponding vessels. With reasonable care, these nerve branches can always be isolated without damaging the vessels. They are cut off and allowed to retract well above the cut end of the tibia. The dorsalis pedis and the medial and lateral plantar branches of the posterior tibial arteries and veins, as well as the saphenous vein, are located at the line of incision, where they are clamped and ligated. The heel flap is then debrided; and all fascia, muscle, and loose strands of devitalized tissue are removed. The abductor hallucis muscle is removed from the medial side of the heel flap and the abductor digiti quinti is removed from the lateral side. The plantar fascia and the flexor digitorum brevis are removed from the center of the heel flap. Removal of these muscles and the fascia is accomplished by sharp dissection with the scalpel. The anterior edge of the heel flap is then beveled with a pair of curved scissors so that, anteriorly, the flap is wedge-shaped (Fig. 4). The tourniquet is then deflated.

Step 3

This consists of clamping, ligating small vessels until a dry field has been obtained, closing the stump, draining, and dressing.

After the tourniquet has been removed, all the bleeding vessels are clamped and ligated with fine ties until the field is as dry as possible. As in all amputations, complete hemostasis is highly important. The heel flap is centered over the end of the stump and held there by one assistant, while it is sutured to the skin of the anterior surface of the leg. No subcutaneous sutures are used, and the resulting suture line is straight across the anterior aspect of the stump. Formerly, the heel flap was fixed to the end of the leg with from

two to four heavy, deep sutures, before the skin was closed, in order to ensure agains displacement. Two rubber dams (Fig. 5) are inserted in all cases where there had previ ously been open wounds. Drainage may not be necessary in absolutely clean wounds

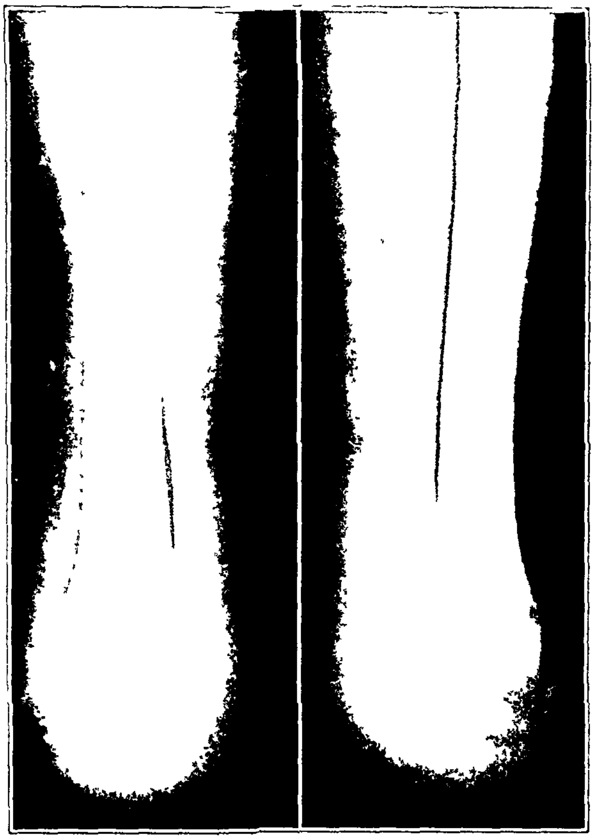

Fig. 10

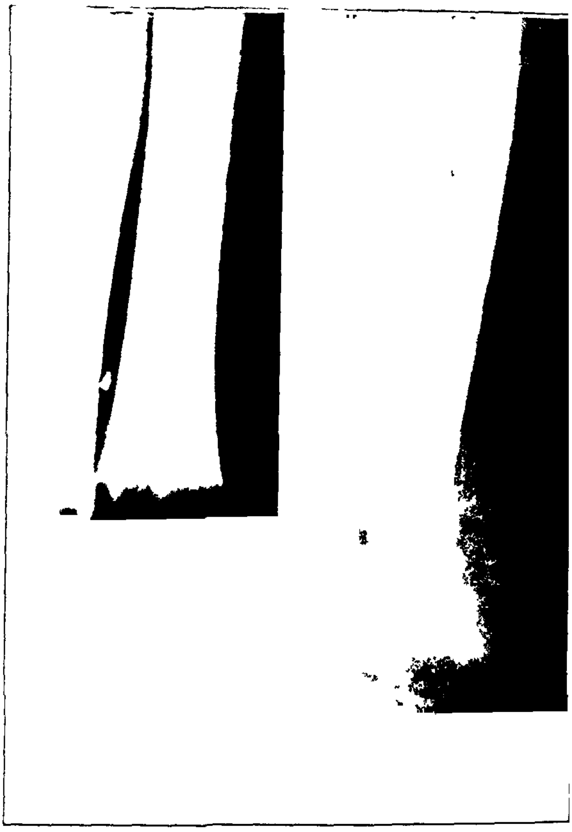

Fig. 11

Fig. 10: Roentgenographic appearance of the Syme stump, done by the technique described.
Fig. 11: Roentgenograms of a poorly performed Syme amputation; the saw line was oblique and too high. The patient was fitted with the usual type of Syme prosthesis, however; and when discharged, eight months after the original injury, had good function.

Fig. 12

Fig. 13

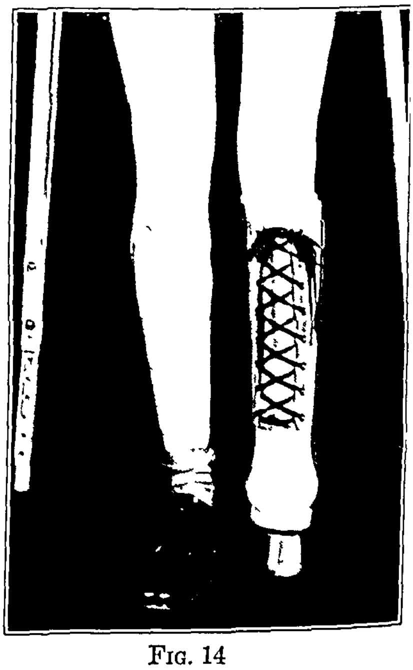

Fig. 14

Fig. 12: Proper method of bandaging a Syme stump; two four-inch elastic bandages are used. The non-padded plaster (Fig. 13) or the brace type of pylon (Fig. 14) is used temporarily for shrinkage of the stump, while patient is waiting for the permanent prosthesis. The plaster pylon 's preferable. In double Syme amputations, the ends of the temporary limbs are made flat for etter balance. (*Figs. 12 and 14 are reproduced by courtesy of W. B. Saunders Company*[1].)

where complete hemostasis has been obtained. The resulting lateral projections of skin forming "dog ears" are never trimmed, as this might devitalize the flap (Fig. 5). The "dog ears" disappear later, as a result of proper use of the compression bandage (Fig. 6). The knee is then held in extension, while a compression bandage is applied over the dry gauze dressing; great care is exercised to hold the heel flap in the center of the end of the long axis of the body while the bandage is being applied. Two four-inch cotton elastic bandages are used (Fig. 12). Adhesive strips to hold the heel flap in position

FIG. 15-A

FIG 15-B

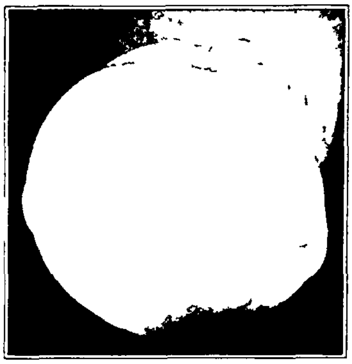

FIG 15-C

Close-up views of a Syme stump, several months after operation Note that the entire weight-bearing end of the stump is covered by plantar skin, which has always been accustomed to weight-bearing

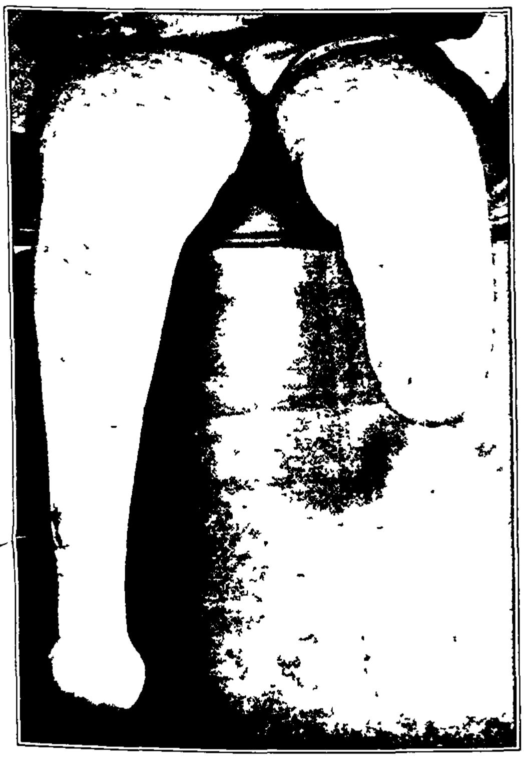

FIG 16-A

FIG 16-B

The advantages of the Syme stump and of the Syme prosthesis over the below-the-knee stump and prosthesis are partly shown (*Fig 16-B is reproduced by courtesy of W B Saunders Company*[1].)

are not necessary. It is important never to apply the postoperative dressing with the knee in flexion, since discomfort will be experienced when an attempt is made to extend the knee.

POSTOPERATIVE CARE

The leg is immediately elevated on pillows, and elevation is maintained from the time the dressing is applied until the wound has healed. The patient is placed in bed, preferably one in which the entire foot of the bed can be elevated with the knee practically straight; only enough flexion is left for the comfort of the patient. The patient is not allowed to turn onto the side on which the amputation has been performed, as this tends to displace the heel flap medially. No postoperative splint is used, since the bed acts as a splint. The first postoperative dressing is changed in twenty-four hours; otherwise the blood on the dressing would dry and removal of the dressing later would be very painful. One drain may be removed at this time if the stump seems dry; but, if there is serosanguineous discharge, both drains are left in place for as long as seven days. The dressing thereafter is changed as indicated,—usually about every forty-eight hours until both drains have been removed, which may be within from two to seven days after operation. No further dressing is done until the fourteenth day, when the sutures are removed. Penicillin or chemotherapy, if used, is discontinued after healing has been assured; this is usually between the seventh and fourteenth day after operation. After the sutures have been removed, the foot of the bed is leveled, and elevation of the extremity is discontinued. The limb is not allowed to hang down until the end of the third week after operation. If the circulation to the heel flap is threatened during the postoperative period, novocaine blocks of the sympathetic trunk are carried out while the patient is in bed. Drains should not be removed until sympathetic blocks have been discontinued, as there may be gross bleeding into the stump if the sympathetic blocks are effective.

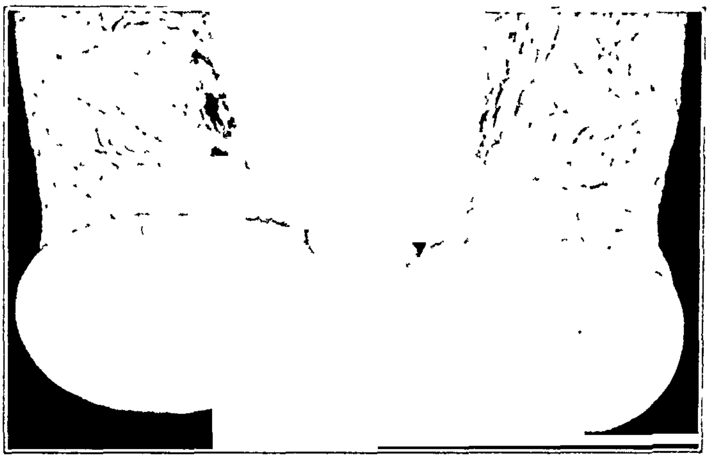

FIG. 17-A

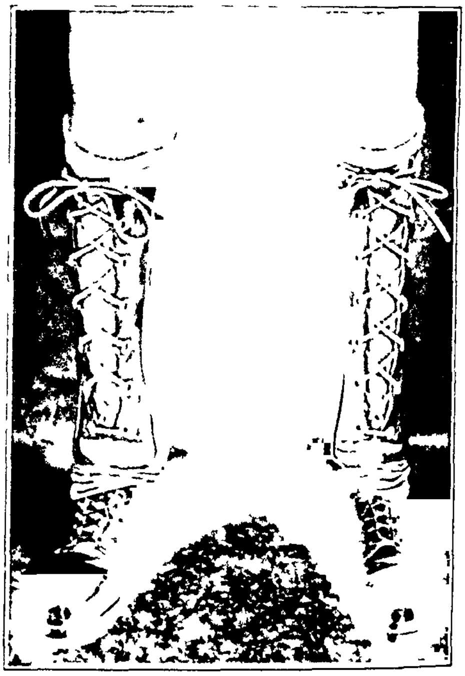

FIG. 17-B

A bilateral Syme amputation, without and with the prostheses. Both amputations were performed at the same time, and primary healing occurred in two weeks. (*Fig. 17-B is reproduced by courtesy of W. B. Saunders Company*[1].)

Ordinarily, a walking pylon is applied between the third and fourth week (Fig. 14). A non-padded plaster with a crutch-tip type of extension is preferable. Patients start weight-bearing on the pylon with crutches for the first week, after which they usually walk with full weight-bearing, without support. After the plaster pylon has been used for about four weeks, a plaster mold of the stump and leg is taken for the permanent prosthesis. In order to make the plaster mold, it is necessary to remove the first pylon; after this a second one is applied, which is worn with active weight-bearing until the permanent prosthesis is ready for use. It requires only a few days after the permanent limb has been applied for

patients to change from the style of walking associated with a peg leg to the normal heel-and-toe gait.

COMPLICATIONS

In this series of seventy-five cases, complications have occurred in approximately 10 per cent. Most of the complications were of a minor nature; but in three cases revision was necessary, following infection or sloughing of part of the heel flap. In no case has reamputation at a higher level been done. Infection has often followed hematoma formation; when hematoma was prevented, infection did not usually occur. Hematoma has also occasionally caused sloughing of a small edge of the heel flap, ordinarily on the medial aspect; but this usually has not required revision or altered the patient's course materially.

Displacement of the heel pad medially or redundancy of the pad has not occurred in any case to an extent sufficient to interfere with good function or to cause dissatisfaction on the part of the patient or the surgeon. There has not been a single instance of phantom limb or of a painful nerve syndrome.

With increased experience, the incidence of complications decreased, so that they rarely occurred in the last 75 per cent. of patients in this series.

RESULTS

No long-time follow-up study has been possible, since the first patient in this series was operated upon only three years ago. However, every patient was followed very carefully until he was fitted satisfactorily with a limb, trained to use it, and either separated from the Service or returned to duty on a limited service status. A few patients are still in the hospital, but all of them have stumps as good as those of the patients who have been discharged. In all of these cases the immediate results have been completely satisfactory to the patient and to the surgeon.

The stumps have all fulfilled the following requirements, which are essential for good functioning of a stump after the Syme amputation:

1. It should have good circulation and good sensation.
2. It should be painless and non-tender.
3. It should be capable of full end-bearing, with or without a prosthesis.
4. It should be suitable for fitting in the conventional way with a prosthesis which requires no apparatus above the knee.
5. There should be no tender scars or other areas liable to break down from the use of a prosthesis.
6. It should be satisfactory both to the patient and to the surgeon.

SUMMARY

The Syme amputation has not in the past been fully utilized by most surgeons in this country. A Syme amputation which meets all the requirements of good function is the best major amputation in the lower extremity. As such, it has definite advantages over amputation below the knee and over most short foot stumps.

The chief disadvantage is the degree of skill and attention on the part of the surgeon, which are required for the best results. If the Syme amputation does not meet the requirements of good function, or if it cannot be made to do so, amputation below the knee is preferable.

The preoperative indications, the operative technique, and the postoperative care are equally important. It is unfortunate that such a small proportion of patients requiring amputations of the lower extremity have the preoperative indications for this procedure, but the experience gained in observing this group of patients has convinced the authors of the superiority of the Syme stump over other stumps of the lower extremity.

It is recommended strongly that the Syme amputation be performed, whenever possible, instead of the more widely accepted mid-leg amputation.

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2. WILSON, P. D.: The Syme Amputation. Surg. Clin. North America, 1: 711-728, 1921.

DISCUSSION

LIEUTENANT COLONEL HARRY D. MORRIS, MEDICAL CORPS, ARMY OF THE UNITED STATES: I want t compliment Lieutenant Colonel Alldredge on his excellent presentation of a difficult surgical techniqu I wish to emphasize again that almost universally, in Army Amputation Centers, a good Syme stump i considered the best result of major lower-extremity amputations, and that much of the criticism in th past has been brought about because of poor selection of cases or faulty operative technique. Our ow experience is based on some forty-two cases which have been done at our Center during the past tw years. Colonel Alldredge has pointed out very definitely the indications for the proper selection of cases i which to perform the Syme amputation. Violation of these clear-cut principles will lead to unsatisfactor results—as is true of any other operative technique—and will bring discredit to the operation. Som criticism in the past has been directed toward these end-bearing stumps, because of the difficulty o prosthesis fitting. Our experience has been essentially that of the authors,—namely, that a Syme pros thesis can be constructed more easily and simply than can a standard below-the-knee prosthesis, and i requires considerably less adjustment. The patient is happy because he does not have any apparatu extending above the knee, and pelvic belts can be eliminated.

We have had no bilateral Syme amputations, but we have had several Syme amputations in com bination with a below-the-knee stump on the opposite leg. Invariably the amputee will state that he feels the Syme is the more satisfactory stump to take the greater part of his weight and thus to relieve the opposite stump.

It might be of interest to mention a variation in operative technique that we have used in Syme amputations at McCloskey General Hospital for the past one and a half years. The subperiosteal resection of the calcaneus has been used by Gordon Dale at the Christie Street Hospital for some time; and, following Dale's advice, we have used this technique in the last twenty-eight Syme amputations. We have been impressed with the fact that, for an operator who is relatively inexperienced in the Syme technique, there is probably less danger of injuring the blood supply of the flap by subperiosteal than by extraperiosteal dissection of the calcaneus, and that the flap adheres very rapidly to the tibial end. In from seven to ten days, it is almost impossible to shift the flap; and, by using a relatively simple postoperative dressing of adhesive strips, we have had no difficulty with shifting of the flap, and the postoperative care has been rendered quite simple. One is concerned, on viewing a postoperative roentgenogram, as to the fate of this large mass of calcified tissue which remains at the stump end; but patients who have been followed for a year have had no particular complications from this source. One must be careful, however, to trim the periosteum around the margins of the flap in order to prevent proliferation; this might possibly make some painful areas, which would give pressure on the sides of the prosthesis.

I believe it is a rather universal feeling on the part of those who have had considerable experience with Syme amputations that the merits of this particular amputation have not been fully appreciated by the profession at large; and that, if proper selection, meticulous operative technique, and adequate postoperative care are carried out, the Syme amputation will find its proper place.

DR. WILLIAM E. GALLIE, TORONTO, ONTARIO, CANADA: I have listened to this paper with the greatest pleasure and I rise now solely to commend the writers for what they have said and to support them in their advocacy of the Syme amputation. Reporting, as they do, nearly a hundred operations done within three years, there isn't anybody who has had more experience with the technique or had a better opportunity to study the early results. Later on, they will be equally competent to report the late results; but in the meantime I can assure them that their hopes are well founded, for it has been the experience of the Toronto group, whom I represent, that the men with Syme amputations walk better, stand up better, and have more comfort and general satisfaction with their artificial legs than men with any other kind of amputation of the lower limb.

The moving picture [shown by the speaker] was prepared for me by my colleagues at the Christie Street Hospital in Toronto. It demonstrates a group of these patients, whose amputations were performed from two to fifty years ago, walking and jumping from a height. The patient whose amputation was performed fifty years ago is an old friend of mine who has played hockey and football, and became one of the leading Canadian cricketers. He put me out of the quarter-finals in the University Club squash racquet tournament, thirty-five years ago.

CONSERVATION OF SHORT AMPUTATION STUMPS BY TENDON SECTION *

BY LIEUTENANT COLONEL HARRY C. BLAIR AND LIEUTENANT COLONEL HARRY D. MORRIS
Medical Corps, Army of the United States

The purpose of this presentation is to describe two surgical procedures which have proved of value in conserving competent function in short amputation stumps.

At McCloskey General Hospital, one of the seven large Amputation Centers set up by the Surgeon General's Office, almost daily the decision must be made as to the necessity of sacrificing short stumps of the leg and forearm because it is impossible to fit prostheses to them. Patients, on the other hand, do not want to lose the power to use their elbows or knees, as the case may be. To aid in this reasonable desire, two surgical procedures have been developed: section of the biceps tendon in the upper extremity, and section of the medial and lateral hamstrings in the lower extremity.

A thorough search of the available literature reveals mention of these procedures in only one instance. In "The Medical Department of the United States Army in the World War", the following brief statement is made: "In these cases [that is, short below-the-knee amputations] the leverage may be increased to the point of utility by removing the fibula, cutting away practically all of the muscular tissue on the back of the stump and severing the inner hamstring". No mention is made of section of the biceps in amputations of the upper extremity.

The stump length of the forearm is measured, according to Kirk, "from the insertion of the biceps tendon, which stands out well when the forearm is flexed at right angles against resistance, to the bone ends of the stump. This gives the true stump length. The minimum stump length allowing the fitting of a forearm prosthesis and furnishing enough leverage to activate it is one and one-half inches." The authors have found that, by excising one inch of the biceps tendon at or near its insertion, approximately two inches in length of useful stump is gained. Following this operation, the true stump length is measured from a point at or near the coronoid process of the ulna.

A functional stump length of one and one-half inches below the knee joint is usually considered the shortest which will allow proper fitting of an artificial limb. The hamstrings, particularly the medial hamstrings, insert at or below this level. Excision of the hamstrings allows a gain of approximately two inches of usable stump length. It is hardly necessary to state that the ability to use a forearm or leg stump, however short, greatly increases the usefulness of the extremity; and any procedure designed to aid in this ability is worthy of consideration.

As stated previously, when the elbow is flexed against resistance, the biceps stands out. Similarly, when the knee is flexed, the hamstrings become prominent. The effect is to crowd the prosthesis off the short

FIG. 1

Schematic illustration of surgical section of biceps tendon. Note increased functional length of stump.

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 23, 1946.

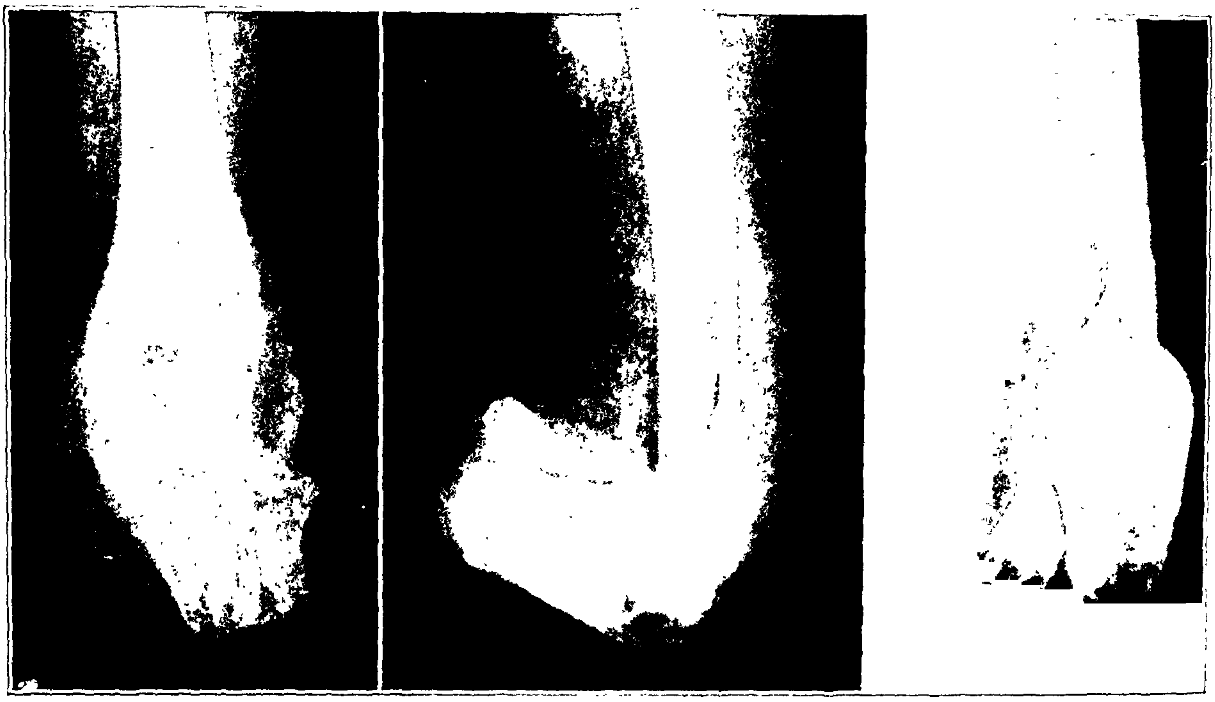

Fig 2-A
Postoperative roentgenograms of short below-the-elbow stump.

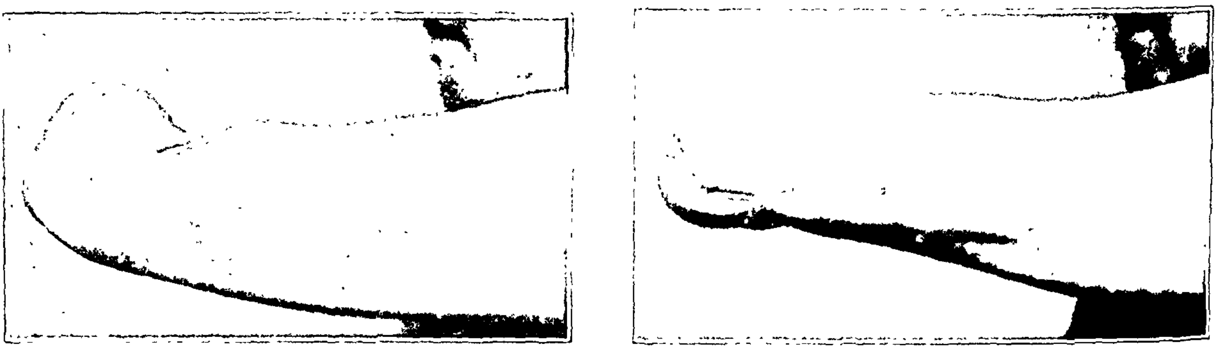

Fig 2-B
Patient illustrates range of motion after operative section of biceps tendon.

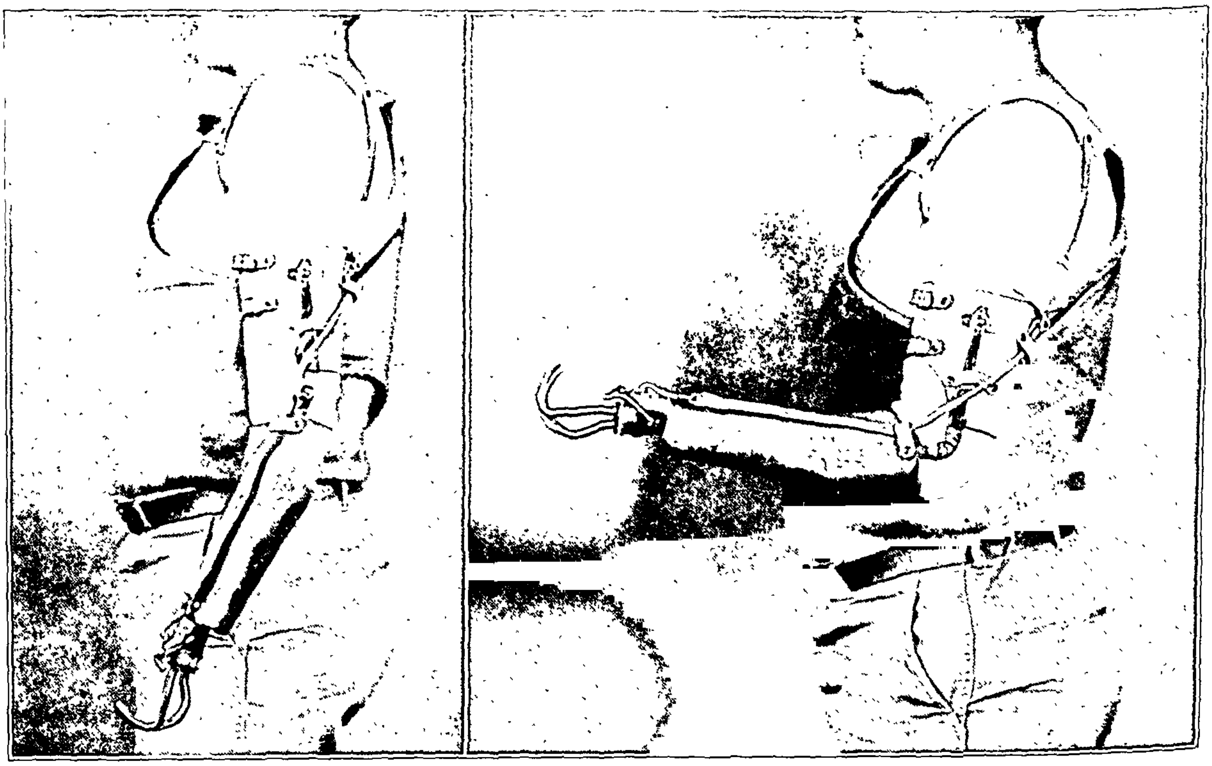

Fig. 2-C
Patient has been fitted with standard prosthesis.

stump; this inhibits the use of the prosthesis in flexion, especially in the upper extremity. Thus the most important movements, which aid in eating, dressing, and shaving, become impossible.

The insertion of the biceps is approximately two inches distal to the coronoid process of the ulna and about the same distance from the elbow joint itself. The biceps muscle, of course, is primarily a supinator of the forearm, and the brachialis is the prime flexor of the elbow joint. The brachialis, being inserted into the coronoid process, is placed close to the anterior surface of the humerus, and extends only a short distance (perhaps one-half inch) onto the stump. Loss of the biceps may decrease the power of flexion slightly, but this is not of material importance. Likewise, loss of rotation of the forearm is of no impor-

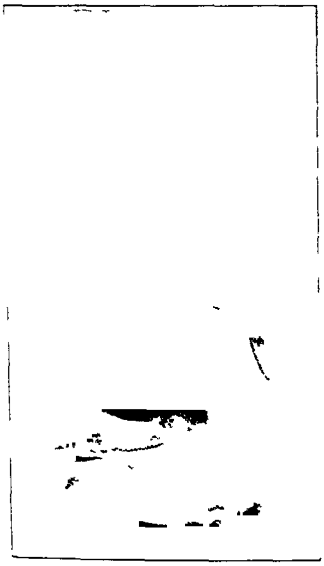

FIG. 3-A

FIG 3-B

Fig 3-A: Roentgenogram, taken after section of biceps tendon
Fig 3-B: Postoperative photographs of stump, following plastic revision and section of biceps tendon.

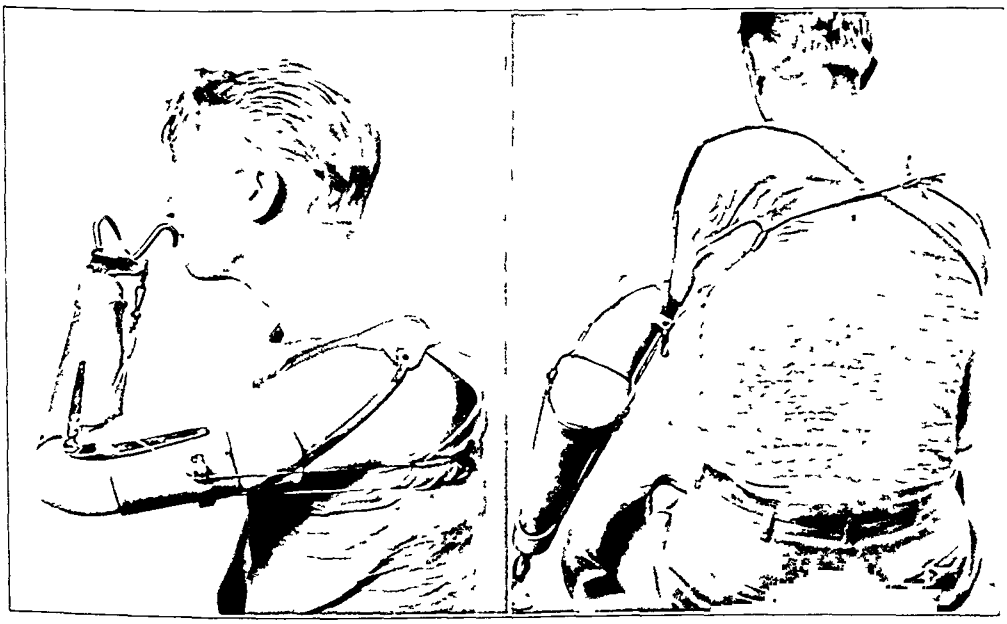

FIG 3-C

Patient has been fitted with prosthesis Note double Northrop cable control and patient's ability to open hook at level of mouth.

tance at this level. A patient with a short stump will not be able to do heavy work, because of the loss of leverage.

At the knee, the hamstrings are the chief flexors and rotators, and their loss does

Fig 4-A

Fig. 4-A: Roentgenograms of short forearm stump, following section of biceps tendon.

Fig. 4-B: Photographs taken after plastic revision and section of biceps tendon.

Fig. 4-C: Patient has been fitted with plastic below-the-elbow prosthesis.

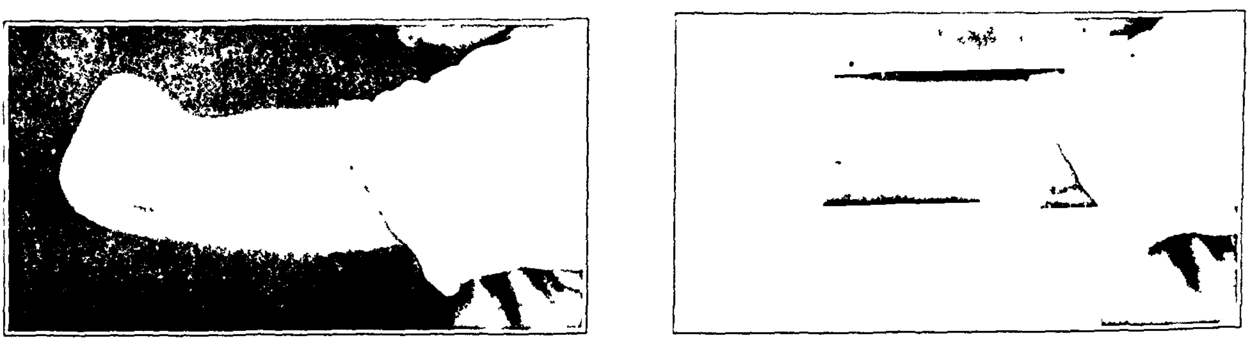

Fig. 4-B

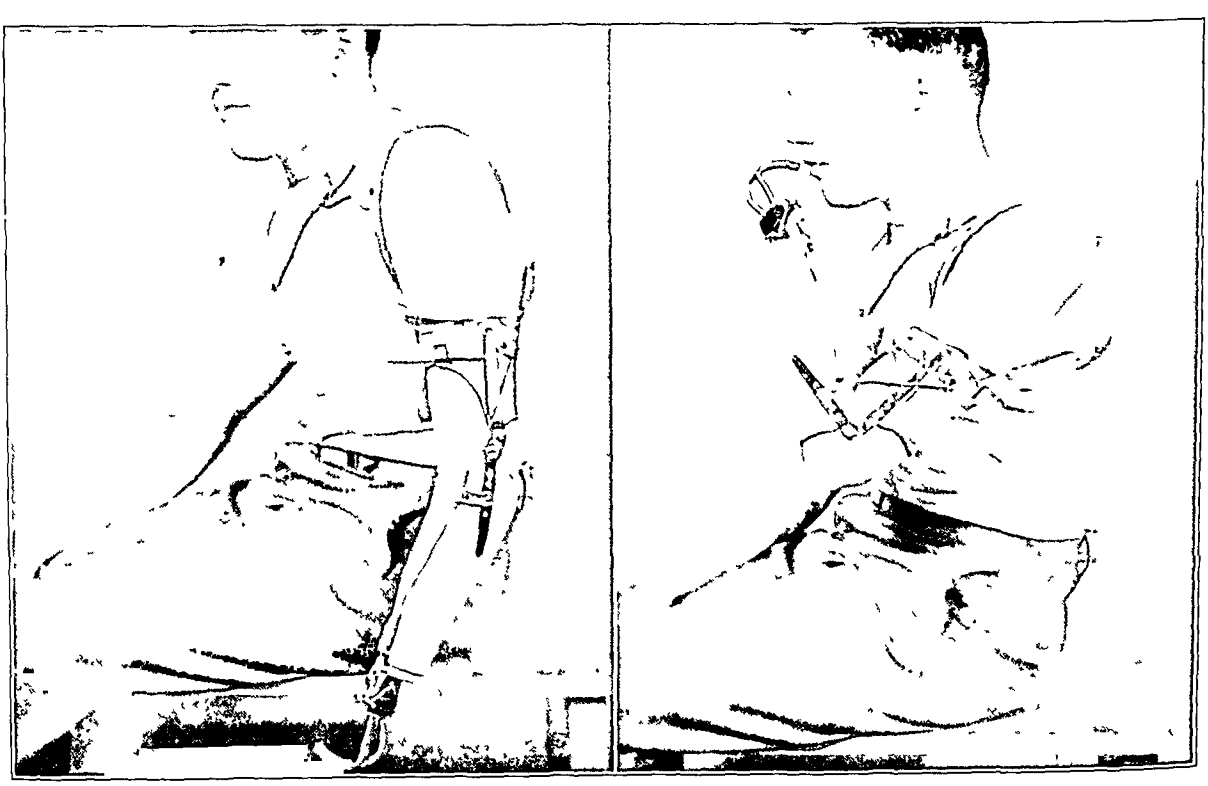

Fig. 4-C

weaken this power. It is conceivable that removal of these important muscles would lead to hyperextension of this joint, which obviously would be the cause of a serious disability. In none of the cases treated by the authors has hyperextension shown any tendency to occur. With the use of a prosthesis, extension with power is the major necessity, as this allows the patient to stand and to bend his prosthetic knee at any angle, while bearing full weight. The power of flexion is of minor importance. The weight of the prosthesis itself will carry out this movement. The two heads of the gastrocnemius arise from the lower condyles of the femur, and this muscle acts as an accessory flexor of the knee joint. In a short-leg amputation, the gastrocnemius is attached to the lower end of the stump, and this acts as the point of insertion The gastrocnemius also prevents hyperextension of the knee joint when the hamstrings are removed.

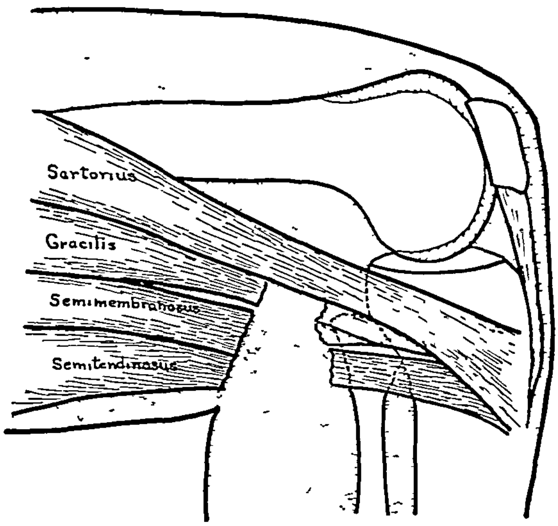

Fig 5

Schematic drawing illustrates operative section of hamstring tendons Note increased length of functional stump obtained (one and one-half to two inches in the average patient)

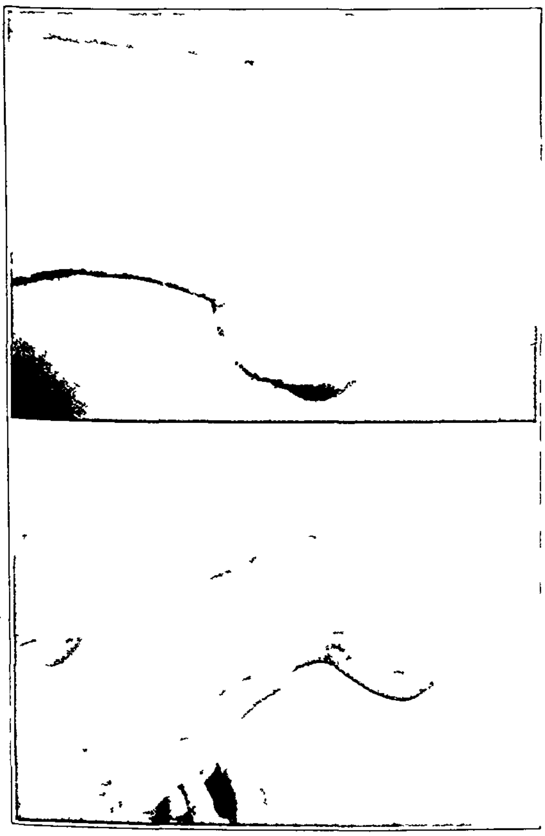

Fig 6-A

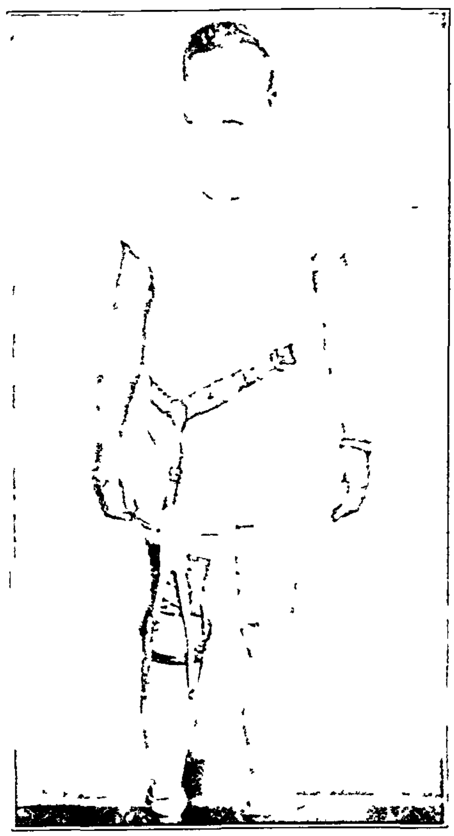

Fig 6-B

Fig 6-A Photographs of short below-the-knee stump taken before and after operative section of hamstring tendons Note the increased functional stump length obtained, which allows fitting of prosthesis

Fig. 6-B Patient has been fitted with standard Army provisional prosthesis

FIG. 7-A

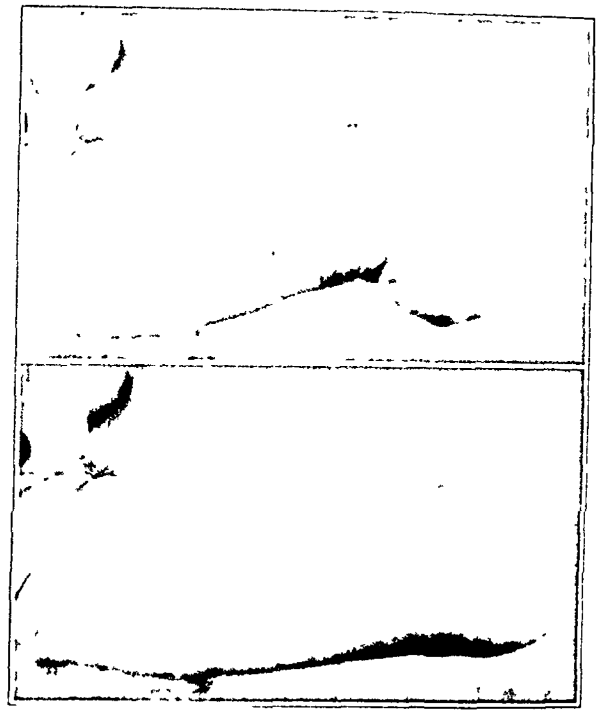

FIG. 7-B

Fig. 7-A: Roentgenograms, before operation (upper) and after operation (lower), of short below-the-knee stump. At operation the remnant of the fibula was excised and the hamstring tendons were sectioned.

Fig. 7-B: Photographs taken after revision of stump and section of hamstrings.

FIG. 7-C

Patient has been fitted with prosthesis; a slip-socket was used in this case. There is no difficulty with stump rising out of the socket during flexion.

OPERATIVE TECHNIQUE

At the time plastic revision of the short forearm stump is undertaken, the terminal scar is excised and equal anterior and posterior flaps are established. By undermining the anterior flap, the insertion of the biceps tendon can easily be found and can be severed at its point of attachment to the radius. The tendon is then pulled down with an Ochsner forceps, and approximately one inch of the tendon is excised. This allows the remainder of the tendon to retract proximally so that it will not become reattached. Any redundant muscle which remains on the lateral aspect of the stump—chiefly the brachioradialis—is thinned down or excised in order to decrease the bulk of the stump and allow a minimum of soft tissue to remain. The investing fascia of the muscle, if present, is sutured over the bone end. If fascia is not available, skin only is sutured over the end of the bone. Drainage is employed for forty-eight hours if complete hemostasis cannot be secured.

In the short-leg stumps, the fibula is excised routinely during plastic repair; the biceps femoris tendon is severed from its insertion at this time. Without any further procedure, it retracts far enough to accomplish the desired purpose. The medial limb of the incision used in shaping the flaps is carried sufficiently high to section the semitendinosus, semimembranosus, and gracilis tendons, so that they are allowed to retract. If extension of this medial incision will endanger the blood supply to the flaps, a small, separate transverse incision is made in the fold of the popliteal space; and the same tendons are sectioned through this incision. The authors have not found it necessary to section the sartorius in any case. In a few patients who had had earlier plastic repair without section of the hamstrings, the medial hamstrings have been cut at a second operation, by the technique described.

RESULTS

During the past ten months, the authors have carried out the procedures described on ten short forearm stumps and twenty-two short below-the-knee stumps, including one patient who had had a bilateral amputation. Only one patient has required reamputation at a higher level; he had a below-the-knee stump with a severe flexion contracture, which was unrelieved by surgical or conservative treatment. All the other patients have been fitted satisfactorily with provisional prostheses.

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THE OVERSEAS TREATMENT OF COMPOUND FRACTURES OF THE LONG BONES *

BY GEORGE O. EATON, M.D., BALTIMORE, MARYLAND

The island-hopping Pacific war, from the Southern Solomons to the Ryukyu chain, was a new type of warfare for the United States forces. Methods and implements of warfare had to be developed or redesigned to meet the new demands. The Medical Corps was no exception,—its mission was the same as in previous conflicts, but the clinical management of the patient had to be adjusted to the ever-present need for evacuation to the rear and to the type and duration of travel. As evidence accumulated and experience increased, hitherto standard procedures gave way to improved techniques. Ideal surgical management of the patient was always in conflict with the function of administration, whose mission it was to evacuate patients so that beds in forward areas were available for emergencies and so that forward units were always kept mobile. Intelligent coordination between professional activities and administrative functions was vital to the best interests of the patient. In the early treatment of battle fractures, no single doctor or group of doctors was actually in charge of the case. The patient received first aid, then was moved toward the rear; shock therapy, débridement of wounds, and immobilization of fractures was accomplished; the patient was moved by stages farther to the rear; and the clinical control of the patient changed hands with each move. Even at the Base Hospital in the overseas theater, the surgeon was in charge of the patient only until it was feasible to evacuate him to the United States. The planes or ships which carried troops and supplies forward were utilized to carry patients to the rear, so that evacuation of patients had to be coordinated with the many other demands on the facilities of the transportation organization. It was necessary to bear in mind always that transportation in the combat area would probably cause a variable degree of deterioration of the patient's general and local condition.

The initial treatment of the battle fracture had three objectives, which, in order of importance, were: the treatment of shock, the management of the wound, and the immobilization of the fracture.

Human blood plasma was available as far forward as the battlefield itself. As a replacement for blood lost by hemorrhage, it was vastly superior to the various intravenous fluids used in World War I; and the comparative ease with which it could be stored, transported, and administered greatly widened its scope of usefulness. During World War II, transfusions of whole blood gradually replaced plasma in the treatment of shock, except in the case of burns or severe crushing wounds. It became common to use as much as four or six liters in a single case. The blood flown from the United States was administered to the patient in Luzon five or more days after it had been drawn from the donor. The blood was packed so that it could be administered just as simply as plasma. Serious transfusion reactions were rare. In one reported series of 750 consecutive transfusions, using blood flown from the United States, there were no deaths, no serious reactions, and only three moderate reactions. Such complications as jaundice, anuria, and oliguria, which have been reported after the injudicious use of large amounts of whole blood, were not observed by the writer. Other measures to combat shock, such as elevation of the foot of the cot, maintenance of body heat, and immobilization of the fracture, were carried out routinely.

After first aid and shock therapy had been administered, the patient was moved to the clearing company from the Battalion Aid Station. Here the soldier had his first opportunity for operative surgery, which, in the case of a compound fracture, was débridement.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

In war surgery, débridement is aimed especially at the prevention of anaerobic cellulitis and clostridial myositis. One seldom saw gas gangrene, except in wounds involving large masses of muscle and in those in which the wound had been allowed to seal over the tract of the missile. To be effective, débridement should be carried out early and should be adequate; and at all times certain axioms must be obeyed: Adequate exposure is necessary to explore all tissues traversed by the missile, to excise all devitalized tissue, and to decompress and aerate the wound; generous incision and relaxation of the fascial layers are necessary to expose devitalized muscle satisfactorily; the excision of skin is held to a minimum; counterincisions for dependent drainage are indicated, especially in the thigh; fragments of bone which are completely detached from periosteum or muscle are excised; and severed tendons or nerves are not resutured during débridement, but only marked for future identification by means of silk or wire ligatures. Débridement in war surgery differed from that in civilian surgery in that it was necessary to lay great emphasis upon leaving the debrided wound wide open. Bleeding points were ligated, but not even partial closure of wounds of the extremities was indicated or justified. In spite of the experience gained in World War I, this lesson had to be learned all over again in the early part of this War. Patients admitted more than forty-eight hours after being wounded were not subjected to débridement, unless evidence of active infection was demonstrated. The relative comfort of a limb which had been adequately debrided, as compared with a similar wound which was under a regimen of watchful waiting, was noted repeatedly.

Local chemotherapy was first used on a large scale in this War. Each soldier was given a packet of sulfanilamide crystals to sprinkle in his wound and a supply of tablets to take by mouth. Following débridement, the application of sulfonamides to the surface of the wound was recommended. Since military surgery permits no experimentation, it was not possible to estimate accurately the value of the local application, because oral administration was employed concurrently. When penicillin became available, the value of its use locally was unproved because of the concurrent parenteral administration. Certainly, progress in wound management has veered away from the introduction of any chemical agent into a wound for its supposed antiseptic effect. Mechanical irrigation of a wound with saline solution or sterile water continues to be a good surgical practice.

One of the most important advances in war surgery has been the extensive adoption of the surgical procedure known as secondary wound closure, which was practised during the closing months of World War I. The optimum time for secondary closure is from four to twelve days after débridement, and the patient must have arrived at a hospital where bed care could be assured for at least fifteen days. Because of these prerequisites, it was not often possible to carry out the procedure in the Pacific Theater. In the Mediterranean Theater and the European Theater, where facilities were greater and distances shorter, this technique was developed. When the patient arrived at the hospital, the original post-débridement dressing was removed in the operating room, under aseptic precautions. If the débridement had been adequate, all superficial wounds and many deep wounds could be closed by secondary suture; following this the part was immobilized, preferably by a plaster cast. The conditions which most often jeopardize results are: dead tissue in the depths of the wound, with purulent drainage; too early motion; and unrecognized foreign bodies adjacent to the wound. Secondary wound closure has been reported successful in 85 per cent. of cases which were properly chosen. Bacteriological studies of wound flora have not proved useful in selecting cases for secondary closure. The great value of secondary wound closure in compound fractures is the minimizing of scar-tissue formation, adjacent to a healing fracture.

Lumbar and thoracic sympathetic block with procaine was utilized to an increasing extent in forward areas for the control of vasospasm following injury. Frequently during débridement the main artery, such as the brachial or popliteal artery, would be observed to be intact, but contracted and pulseless. Following débridement, sympathetic block

would be accomplished and would be repeated daily, if indicated, until warmth and pulsation returned to the distal portion of the extremity. The extreme value of this procedure in such cases should always be kept in mind.

Statistics show that 68 per cent. of battle wounds involve the extremities, and that about half of the extremity wounds result in fracture, so that about 34 per cent. of battle wounds are compound fractures. These battle fractures differ from the usual civilian fracture in several important ways: They are usually markedly comminuted, due to the high velocity of impact. There is usually extensive soft-tissue damage. The tendency to shortening and overriding is much less than in simple fractures. The time of healing (formation of callus) is prolonged, and the time interval in which reduction of displacement can be accomplished is extended.

On the battlefield, splinting of long-bone fractures was part of the routine first aid. The upper extremity was usually bound firmly to the chest wall; traction splints were seldom used. The thigh and leg fractures were placed in traction in an Army leg splint, if available; if not, they were splinted to any rigid material at hand, such as boards, tree limbs, or rifles. At the Battalion Aid Station, such improvised splints would be replaced by the Army leg splint. This is a Thomas splint in which the metal ring has been replaced by a soft, pliable leather, which forms the posterior half of the ring, and by a strap and buckle, which form the anterior half. Adjustment of the strap and buckle so that the posterior part of the ring would not slip up over the ischium, and yet so that there was no impediment to return circulation at the groin, was extremely difficult. Periods of travel were comparatively prolonged, and plaster was substituted for immobilization as soon as the wound had been debrided. In order to save time and manpower, compound fractures of the femur were debrided with the limb in traction on a portable fracture table,—either the commercial type or an improvised imitation. In this way, general alignment and the full length of the bone could be restored; this was the goal in reducing the fracture, at this stage.

Plaster immobilization consisted of a "one and one-half" hip spica, which extended from the costal margin to the knee on the sound side and to the base of the toes on the injured side. The cast was reinforced with a strut and was well padded and split. In our hands, the Tobruk splint was unsatisfactory. Fractures of the lower part of the femur which could be immobilized in a Tobruk splint could as well be immobilized in a toe-to-groin cast. In so far as possible, traction casts were not used during transportation. All compound fractures above the elbow joint were immobilized, after débridement and general realignment, in shoulder spica casts, with the upper arm in from 20 to 40 degrees of abduction. The hanging cast proved to be totally ineffective and uncomfortable. Compound fractures of the other long bones, after débridement, were immobilized in padded plaster casts which included at least the joint above and the joint below the fracture. Because of the hazard involved, the skin-tight plaster technique was not used during transportation.

The journey to the Base Hospital was begun by the patient with a compound fracture after shock therapy had been completed, the wound had been debrided, and the fracture immobilized. In the early days of the New Guinea campaign, the distance was about fifteen hundred air miles and might be made by ship or plane, with numerous stops and ambulance rides *en route.* Stops would be made at military hospitals, and a tendency developed to change the cast at each stop in order to observe and report the condition of the wound. For this reason, the rule was made that a patient would not be subjected to change of cast if his temperature was normal, his injured limb was comfortable, and the circulation in the toes or fingers was normal. This rule proved to be satisfactory and practical. All patients with compound fractures had a normal expectancy of not returning to duty within four months, and were therefore destined to complete their convalescence in the United States. They were evacuated to General Hospitals in rear areas for treatment until they could be evacuated from the Pacific Theater.

The General Hospital was especially equipped and staffed to investigate diagnostic problems and to deal with therapeutic problems. A critical estimate was made of the patient's general and local condition, and an accurate history was culled from his records. Casts were removed and the wounds were revised and closed secondarily, if feasible; or further débridement was performed, if indicated. At this Hospital, the choice of methods for definitive treatment of the fracture was made. Open reduction and fixation were usually reserved for those cases in which attempts at closed reduction had failed. Patients with fractures of the arm, forearm, or leg continued their convalescence in padded plaster casts, provided that, by manipulation or by wedging, satisfactory reduction could be obtained and maintained. Traction, when indicated, was usually of the skeletal type. Distraction of the fragments was apt to occur with the weight values usually used in simple fractures. External skeletal fixation was seldom used, perhaps because the apparatus was scarce, or perhaps because immobilization of soft-tissue wounds speeded up healing and diminished the tendency for spread of infection.

A series of thirty-five cases with fractures of the femur, admitted to a General Hospital in the Pacific area, have been reported by Hochwalt, Rogers, and Culmer.[1] The average time which elapsed between injury and admission was twenty-five days. Ten patients were in satisfactory positions in plaster and were not disturbed. Nine patients had simple fractures with malposition; and, in eight of these, open reduction was necessary to secure satisfactory positions. Sixteen patients had compound infected wounds with malposition, and in all of these the fractures could be reduced satisfactorily by skeletal traction. This illustrates well the statement that the compound fracture received in battle has less tendency to become displaced in plaster, and a longer time interval exists within which closed reduction of the displaced fragments can be accomplished. General Kirk strongly favored the routine use of balanced traction for fractures of the femur. If the patient arrived with the fracture fragments in good position in plaster, no change was made until consolidation of the fragments had occurred. When traction was indicated to correct malposition, skeletal traction applied through the tibial crest appeared to be the most satisfactory. When traction was indicated to maintain full length, the Russell-Hamilton suspension traction proved to be adequate, if the skin areas were available. While patients with fractures of other long bones could be evacuated to the United States promptly without risking the occurrence of displacement of the fragments in plaster, it was necessary to keep patients with fractures of the femur under treatment overseas until sufficient healing had taken place so that malposition would not develop after transfer to a plaster cast. This period varied from eight to sixteen weeks.

Statistics of World War II will show a marked improvement over those of the last War in the rate of survival and the escape from permanent crippling disabilities, subsequent to war wounds of the extremities. This improvement will not be primarily the result of advances in chemotherapy, but rather of advances in shock therapy and in wound management. Further improvement is possible. The administration of the Medical Corps must take a more active interest in the clinical welfare of the patient. The visit of the Surgeon General to the Pacific Theater in the early months of 1945 was a most powerful and pleasant stimulus to the average professional medical officer. Here was the highest ranking medical officer in the Army of the United States on a tour of inspection, making clinical bedside rounds and giving helpful instruction and criticism to the ward officer. The consultant system, begun in World War I and enlarged in this War, is the key to improving the quality of medical service rendered the patient. Particularly in the more forward areas, the average young surgeon is loaded with more responsibility than he has been trained to assume. He is notably conscientious and anxious that his patient should receive the best possible treatment. He is unable to follow the patient's progress after evacuation. Circulars and memoranda have a way of not reaching him. Only by the visits of consultants can he learn of his errors and of new methods and procedures. Military surgery has

made great strides, but even more progress will be made if more emphasis is placed upon the quality of professional accomplishment.

1. Hochwalt, W. R.; Rogers, S. C.; and Culmer, A. E., Jr.: Fractures of the Femur. Bull., U. S. Army Med. Dept., No. 88, pp. 86-90, May 1945.

DISCUSSION

Dr. Edwin F. Cave, Boston, Massachusetts: During the early months of the campaign in the Pacific, the care of compound fractures was not the best,—not because of neglect on the part of the Medical Corps, but because of the small number of adequately trained medical personnel available in the Theater, because of the lack of transportation, and the great distances of fixed hospitals from the areas of combat.

When evacuation of patients by air became more efficient in late 1943, 1944, and 1945, no longer did we receive at our General Hospitals malnourished, exhausted, and dehydrated patients, many of whom had malaria and septic compound fractures,—a situation frequently encountered during the early New Guinea campaign. Due to air evacuation, particularly from the Philippine battles, patients came to General Hospitals within a few days. All were reasonably well nourished; their blood losses were not great. Their wounds had been well cared for, and plaster immobilization had been well applied. Malaria was a much less frequent complication.

Upon arrival at the General Hospital, every "battle fracture" was seen promptly by a ward officer. He evaluated the general condition of the patient: for evidences of sepsis or blood loss; his state of nutrition and dehydration; and also the condition of the injured extremity,—its circulation, motion of the toes or fingers, and evidence of local sepsis.

If there was evidence of local sepsis or of circulatory difficulty, the patient was taken immediately to the operating room and the cast was removed. Not infrequently a small, inadequately debrided wound was found. Such wounds were opened widely, fascial planes were released, and the wounds were packed loosely with fine-meshed gauze. We questioned the extensive use of vaseline gauze, which, at times, actually plugged the wound.

The lower extremities were suspended in the half-ring splint, with skeletal traction through the tibial tubercle or the os calcis. Plaster was used more often for the upper extremity, unless it was feasible to use skeletal traction through the olecranon. Hot fomentations were applied locally, and penicillin therapy was begun. Transfusions were used, as indicated.

All femora which were in good position and not in danger of sepsis were left in plaster. The septic ones, or those with overriding, were placed in the half-ring splint, with skeletal traction through the tibial tubercle. Practically all were pulled into good alignment, if they were no older than three weeks. Essentially all patients whose fractures had kept good position during their evacuation to our Hospital were returned to the United States shortly after their reception, their wounds permitting, but only after a change of plaster. Patients with fractures, particularly of the femur, which required reduction in our Hospital, were kept there until there was sufficient consolidation to prevent displacement during transportation to the United States.

Based upon more than three years' experience in a General Hospital overseas, I have the following comments which may interest the surgeons who served in the forward areas. It is not intended to criticize the surgeons in the advance stations, whose work was, as a rule, of the highest order.

1. Adequate débridement was too often not done.
2. Wounds were at times too tightly packed with vaseline gauze; this was particularly true in the early days of the War and was not entirely unheard of as late as 1945.
3. Not infrequently we believed that bone was sacrificed unnecessarily at the original débridement. The orthopaedic surgeon in the Reconstruction Hospital will beg of you to preserve every particle of bone which has the slightest chance of survival, with the hope that it will bridge the gap between the main fragments and thus make the eventual grafting simpler.
4. Plasters applied in the forward areas were, on the whole, satisfactory. If there was adequate padding, there was no need to split the plaster casing prior to the evacuation to the rear.
5. Wire splints were not good for transportation.

Dr. W. H. McGaw, Cleveland, Ohio: From the Guadalcanal offensive to the completion of the initial campaigns in New Guinea—at Buna, Lae, and Finschaefen—our General Hospital, which happened to be the first to arrive in the Southwest Pacific, was left farther and farther in the rear of the fighting.

In those early campaigns, the wounded reached us from four to six weeks after injury. During that time, most of our patients were transported by hospital ship or overland in long Australian hospital trains. We frequently received from 300 to 500 patients in a convoy, and in one instance 700 patients were received in one day. Many of the patients who arrived by hospital train spent two or three nights

on the train. Medical officers from our General Hospital were always sent to meet these convoys about a day before their arrival. These officers then checked each patient's general condition and diagnosis. Patients were tagged for a particular service or ward before they left the train, and those in doubtful condition were earmarked for the first ambulances and for immediate surgical attention. Wounds were inspected, and casts were changed immediately, if necessary. Many of the patients received immediate transfusions of plasma or blood. All of the patients with compound fractures reached us in plaster casts, and, with the exception of those with fractures of the femur, most of them remained in plaster. Those with fractures of the femur were usually put in balanced skeletal traction until an adequate callus had formed. Then the patient's limb was immobilized in a plaster spica for the long trip home across the Pacific, which usually took from three to four weeks.

In some of the early cases, tight vaseline packing was found in the wounds; presumably this treatment was used for the control of hemorrhage. A general anaesthetic was occasionally needed in the removal of such packing. Rarely did a patient reach us without adequate débridement of the wound.

In the spring of 1944, our Hospital was moved from Melbourne, Australia, to Finschaefen, New Guinea. There we began receiving much more recent cases. A few of these were transported by air, reaching us within two to four days. Most of them, however, reached us by ship in from ten to fourteen days following the injury.

The general condition of the patients in New Guinea always received primary attention. It was the usual thing for a soldier to have lost from fifteen to twenty-five pounds even before he received his wound. Most of the patients with compound fractures showed signs of secondary anaemia and dehydration on arrival. As Colonel Eaton has mentioned, this condition of the patients facilitated reduction of the fracture, but definitely delayed its healing. Many of the patients arriving during this period had been evacuated from beach installations, and they had frequently been loaded and landed by water craft and by amphibious ducks of all kinds. They occasionally arrived with their casts softened by salt sea spray and even by vomitus. Maggots were found in some of the wounds. In addition, a great number of the patients had high fever, due to malaria or hepatitis. Large quantities of whole blood and plasma were sometimes needed over a long period of time. Practically all of the compound fractures were boarded to be sent to the Zone of the Interior as soon as transportation was available and as soon as the condition of the fracture and wound was suitable for a trip across the ocean of from three to four weeks, usually not in a hospital ship. The patients with fractured femora, naturally, had longer stays in our Hospital than any other group. Their average stay was about three months.

The wounds were occasionally closed secondarily, and an effort was made to cover any exposed bone at the earliest possible moment. This was sometimes possible with relaxing incisions; split-thickness grafts and pedicle skin grafts were occasionally used to cover large wounds before the patients were sent home.

The following table lists the types of compound fracture evacuated to the Zone of the Interior from our Hospital between April and September 1944. These patients were wounded during the Aitape, Hollandia, Biak, Noemfoor, and Sansapoor campaigns.

	Number	*Per Cent.*
Tibia and fibula	58	27
Femur	49	22
Humerus	37	17
Radius and ulna	27	12
All others (except spine and skull)	49	22
Total	220	100

Twenty per cent. of the patients in this group sustained more than one compound fracture; 15 per cent. had nerve involvement as well as the compound fracture. During this same period, only thirty-three simple fractures were boarded to the Zone of the Interior.

During these extensive campaigns in the Southwest Pacific area, our Orthopaedic Consultant, Colonel Eaton, devoted much of his time to improving the care of the wounded. He saw these patients in the portable, station, and evacuation hospitals, as well as in the rear general hospitals. During the active campaigns he was close to the firing, whenever possible, helping a team in one hospital and then another. Eventually, he would see many of the same patients at the rear hospitals. He was constantly returning with fresh suggestions and information for improvement in the care of patients. Dr. Eaton called this "leg work", when actually his was the important "head work" of constant progress.

MUSCLE TRANSPLANTATION FOR PARALYSIS OF THE RADIAL NERVE

BY CAPTAIN HAROLD ALTMAN AND CAPTAIN RAYMOND H. TROTT

Medical Corps, Army of the United States

In wartime a relatively large number of cases of paralysis of the radial nerve, which are usually associated with compound fractures of the lower two thirds of the humerus, are seen in Neurosurgical Centers. In cases where the nerve has been explored and found to be injured to such an extent that repair cannot be accomplished, tendon transfer at the wrist results in function of the hand and wrist which approaches the normal in approximately two or three months. The authors are presenting the early results observed when tendon transplantations have been performed for irreparable lesions of the radial or dorsal interosseous nerve, which have had the maximum benefits of neurosurgery. If a careful technique has been observed, a good result can be obtained in every case.

The authors have had the opportunity of carrying out these procedures on twenty-two patients * at McCloskey General Hospital. The technique of Billington, with the right-angle incision on the extensor surface of the lower end of the forearm, was employed in the earlier cases, and resulted in either a slough of the incision near the angle or considerable oedema of the fingers and dorsum of the hand. It was necessary to keep the patient in bed with the upper extremity elevated for three weeks in order to overcome the oedema. In addition, it was often technically difficult readily to identify and release the necessary tendons for transplantation without an undue amount of traumatic handling of the tissues.

The difficulties encountered by the authors were contrary to those recorded by many experienced and capable authorities doing this type of work, who advocate wide exposure. The authors found that, by making several minor changes in the usual accepted techniques, better results could be produced in a shorter time, with no postoperative oedema; and early ambulation was possible on approximately the second day after operation.

The early results of the procedures were so encouraging that they were performed in a few cases in addition to nerve repair. The advantage of the operation in this group is the speed with which the paralyzed hand is transformed into a useful member. The transplanted muscles act more efficiently than a splint in helping to maintain the dorsiflexed position of the wrist during the recovery of the nerve. The operation has also helped to dispense with many months of physiotherapy, and has permitted early discharge from the Hospital. The possibility of overdevelopment of the dorsiflexors in those cases in which the radial nerve regains its power has been kept in mind by the authors. Unfortunately, it has been impossible to do a follow-up study after a lapse of time sufficient to justify a positive statement.

TECHNIQUE

The upper extremity is elevated during the preparation of the skin. A sterile elastic bandage is utilized to "milk" the hand and forearm completely of venous blood. A tourniquet, similar to a blood-pressure cuff, is applied to the arm and the pressure is kept at 260 millimeters of mercury.

The tendon transplantations are performed proximal to the dorsal carpal ligament, which is not disturbed (Fig. 1, *A*). A two-inch transverse incision is made on the extensor surface of the distal portion of the forearm, approximately one-half to three-quarters of an inch proximal to the proximal border of the dorsal carpal ligament. The skin edges are undermined for a distance of approximately three-quarters of an inch. The underlying large veins are carefully avoided. A small self-retaining retractor is inserted. A two-inch

* An additional six patients have been operated upon and followed since this series was completed. The results confirm the conclusions already formulated.

longitudinal incision is made through the subcutaneous tissue and the deep fascia, parallel to the superficial veins, over the region of the extensor digitorum communis tendons. These tendons are isolated, along with that of the extensor indicis proprius, and are retracted to the ulnar side of the wound with rubber-dam retraction. The tendon of the extensor digiti quinti proprius is isolated and placed in the same rubber-dam retractor.

The tendons of the abductor pollicis longus and the extensor pollicis brevis are then isolated and brought into the operative field by slipping a curved Kelly clamp under them. A rubber-dam retractor isolates them at the radial side of the incision. Lister's radial tubercle is palpated and is a landmark for the nearby tendon of the extensor pollicis longus. This tendon is included with those of the extensor pollicis brevis and abductor pollicis longus in the rubber-dam retractor.

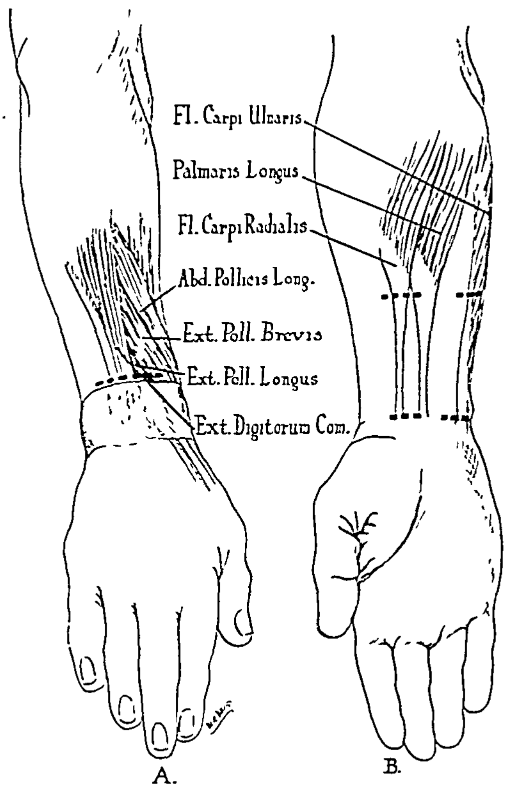

FIG. 1

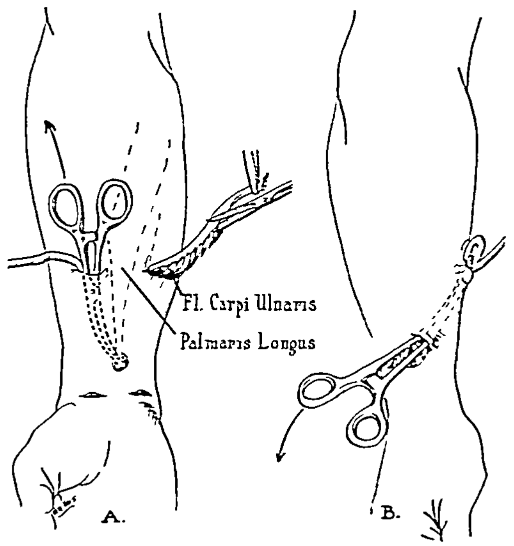

FIG. 2

Fig. 1: Demonstrates the incisions used in the operative procedure.

Fig. 2: *A*: The tendon of the flexor carpi radialis has been pulled free through the proximal incision. Clamp is on palmaris longus tendon, which is being carried to the same proximal incision. The flexor carpi ulnaris tendon has been retracted through its proximal incision and is being freed of its attached muscle fibers.

B: Flexor carpi radialis tendon is being carried through its subcutaneous tunnel to the extensor surface of the forearm. The palmaris longus tendon is lying free, awaiting its turn to be brought through the same tunnel.

The forearm is fully supinated and the tendons of the flexor carpi ulnaris and the flexor carpi radialis are identified by palpation, with the hand in cock-up position. It should be noted that the tendon of the flexor carpi ulnaris is on the radial side of the muscle, at the wrist. It is superficial to the volar carpal ligament, and is found approximately one-half inch from the ulnar border of the wrist. Although most surgeons have utilized an incision four or five inches long, so as to expose the entire course of these tendons, the authors have found it possible to free them through a small, half-inch transverse incision made in the skin over each tendon in the region of the distal transverse crease of the wrist (Fig. 1, *B*). The tendons are severed and are clasped with Kocher clamps. By exerting gentle traction on the proximal end of the severed flexor carpi ulnaris tendon, its location at the mid-forearm can be palpated. A half-inch transverse skin incision is made at this level. The Kocher clamp grasping the flexor carpi ulnaris tendon is then passed proximally

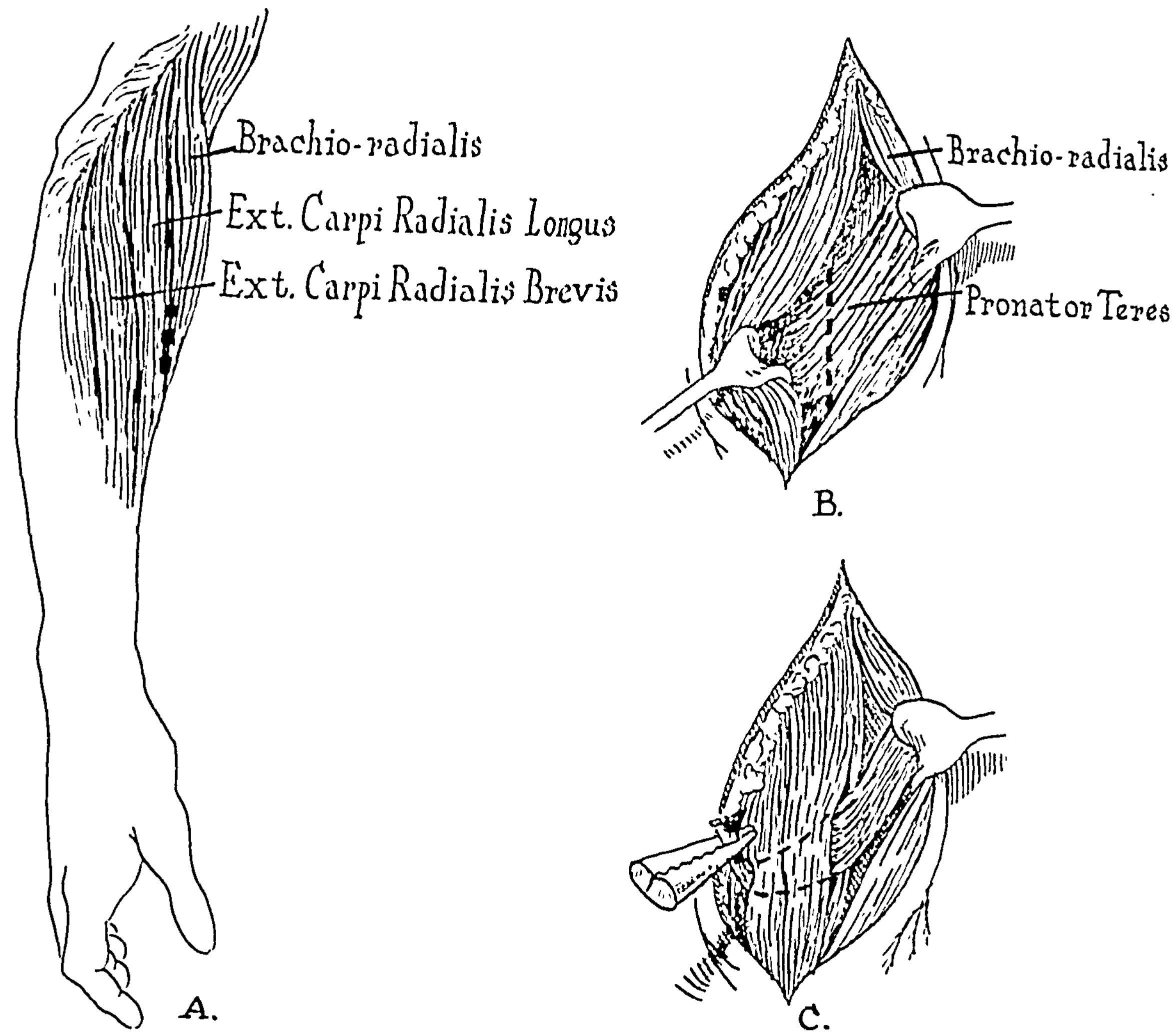

FIG. 3

A: Demonstrates approximate level of incision to isolate pronator teres tendon.

B: Brachioradialis is retracted to one side, extensor carpi radialis longus and extensor carpi radialis brevis to the other side. The underlying pronator teres tendon has been severed.

C: Tendon of pronator teres has been passed through musculotendinous portion of extensor carpi radialis longus and extensor carpi radialis brevis.

to the proximal transverse incision, and the tendon is extracted through it (Fig. 2, *A*). The muscle fibers on the flexor carpi ulnaris tendon are removed with a scissors, so that only the tendon remains. Some difficulty has been encountered in releasing this tendon, and this can probably be overcome by using tendon strippers of the proper gauge. A curved Kelly clamp is passed subcutaneously from the ulnar portion of the incision on the extensor surface of the forearm, proximally around the ulnar portion of the forearm, to the proximal incision on the flexor surface. The previously freed tendon is grasped and threaded through its subcutaneous tunnel. This should be deep to the large veins of the forearm.

The severed flexor carpi radialis tendon is passed proximally through a similar incision over the mid-portion of the flexor surface of the forearm, and then distally, subcutaneously, on to the radial portion of the extensor surface of the forearm (Fig. 2, *B*). The four small transverse incisions are closed.

The forearm is next placed in mid-position, and a longitudinal incision, one and one-half inches in length, is made over the site of insertion of the pronator teres tendon (Fig. 3, *A*). The brachioradialis muscle is retracted to one side; the tendons of the extensor carpi radialis longus and the extensor carpi radialis brevis are retracted to the other side The pronator teres tendon is severed along its radial insertion (Fig. 3, *B*).

The wrist and fingers are dorsiflexed, and the thumb is dorsiflexed and abducted by the assistant. This position must be maintained for the remainder of the operation and until a plaster splint has been applied.

A stab wound is made transversely through the substance of the tendons of the extensor carpi radialis longus and the extensor carpi radialis brevis. The pronator tendon is passed through these tunnels and sutured to each tendon with interrupted sutures of No. 0 chromic catgut (or silk) by the method described by Mayer (Fig. 3, *C*). The protruding portion of the transplanted tendon is excised. This is necessary to prevent adhesions being formed with the surrounding soft tissues, which will limit range of motion. Skin closure is effected.

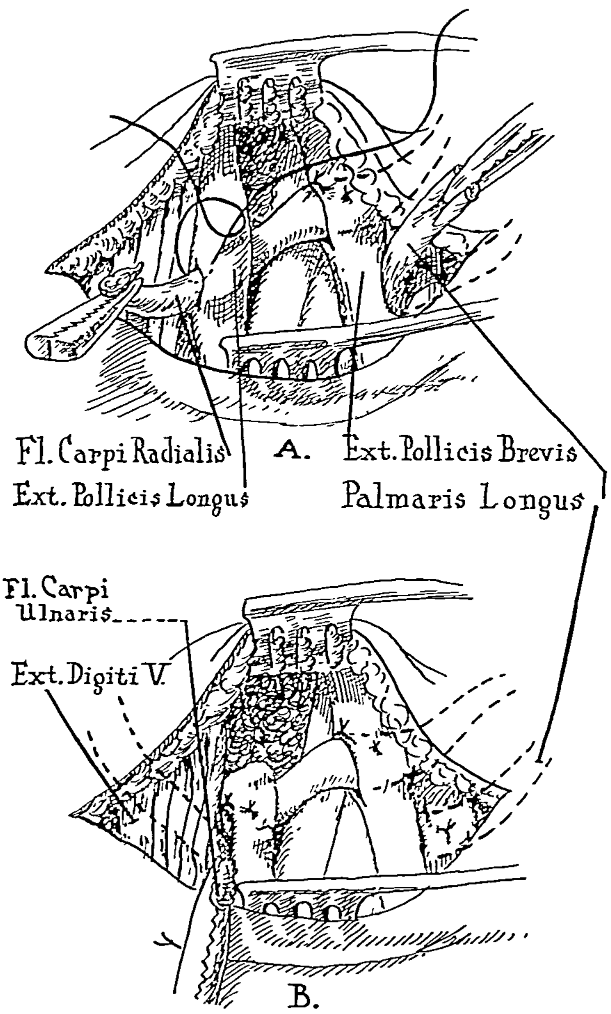

FIG. 4

A: Tendon of palmaris longus has been threaded through that of abductor pollicis longus. Flexor carpi radialis has been placed through tendons of extensor pollicis brevis and extensor pollicis longus.

B: Tendon of flexor carpi ulnaris has been brought through tendons of extensor digiti quinti proprius, extensor digitorum communis, and extensor indicis proprius.

The tendon of the flexor carpi ulnaris is similarly passed through and sutured to the extensor tendons of the index finger, middle finger, ring finger, and little finger, by the buttonhole technique of Mayer (Fig. 4, *B*). The holes in the recipient tendons are made with a mosquito clamp, which is pushed firmly through them at the desired levels. It was found that a No. 11 blade occasionally severed a small segment of one side of the buttonhole, if the operator was not unusually careful. The clamp method provides some additional safety, and was therefore adopted. The transferred tendon is passed through the newly made buttonholes, and is fixed to each paralyzed tendon by means of a small suture through both the proximal and distal ends of the buttonhole. That of the flexor carpi radialis is likewise passed through and sutured to the tendons of the thumb (the extensor pollicis longus and extensor pollicis brevis, and the abductor pollicis longus) (Fig. 4, *A*). The extensor pollicis longus tendon is divided one-fourth of an inch proximal to the muscle transfer. The fascia and subcutaneous tissue are closed with interrupted sutures of No. 0000 chromic catgut, which cover the recently transplanted tendons. The skin is closed.

In suturing the transplanted tendons into the donor tendons, the site of transfixion is chosen by pulling taut the paralyzed tendons and approximating the tendons to be transferred. Too much tension, however, is not desirable; it should approximate the physiological in degree. Sterile dressings are applied and are held in place with sterile sheet cotton. A plaster-of-Paris splint is then applied to the flexor surface of the extremity, maintaining the fingers in complete extension and the wrist in 30 degrees of cock-up position. The plaster extends from the proximal third of the forearm to the distal interpha-

langeal joints, and is held snugly in place with an elastic bandage. The tourniquet is then removed. No case of tourniquet paralysis has been encountered.

If the lesion is that of a dorsal interosseous nerve, the transplantation of the pronator teres tendon is not necessary.

After operation, the forearm is elevated by means of an irrigation stand for from one to two days. If no oedema is present, the patient is allowed to get up, with his upper extremity in a sling. From the time the patient has recovered from the anaes-

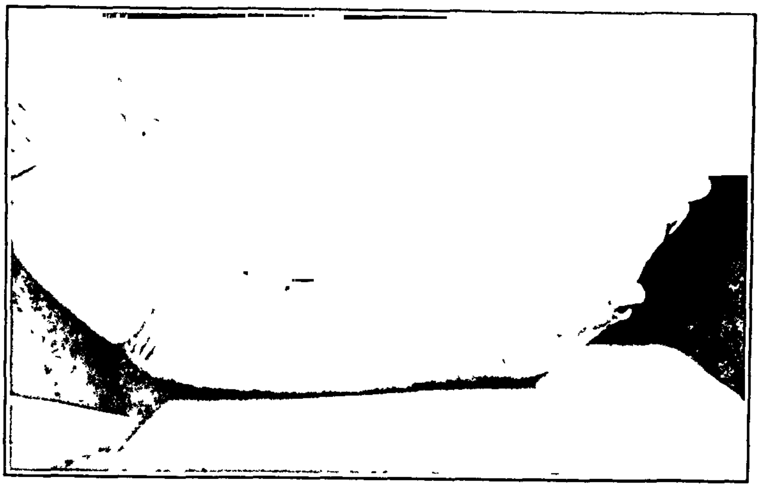

Fig. 5-A

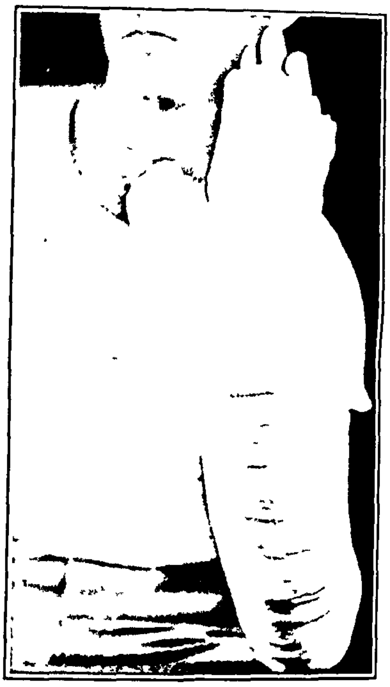

Fig. 5-B

Demonstrate type of plaster-of-Paris splint used for postoperative convalescence.

thesia, he is encouraged to move the ends of his fingers. At the beginning of the fourt week after operation the sutures are removed, and gradual active motion of the trans planted tendons is started. The patient is followed closely and is instructed in the prope use of the transplanted tendons, so that re-education is effected in a relatively short tim At the beginning of the fifth week, the plaster splint is worn only at night; it is discarde at the sixth week. The patient is started on some type of occupational therapy, requirin the use of his fingers and hands. Physical therapy should not be employed in these case since *active* use of the tendons is the best method of muscle re-education.

SELECTION OF CASES AND RESULTS

Operation was performed upon those patients who had an irreparable injury, witl loss of function of the radial or dorsal interosseous nerves. There had to be sufficien strength in the tendons to be transplanted so that they might act as motors.

In injuries of the dorsal interosseous nerve, the flexor carpi ulnaris and flexor carp radialis were utilized rather than one of the extensor carpi radialis tendons, because botl of the latter are necessary to stabilize the wrist in order to allow for good grip of the fingers

Recently the palmaris longus tendon, where present, has been transplanted into th abductor pollicis longus tendon, rather than the flexor carpi radialis being used in all three thumb tendons. This, according to Bunnell, gives a better working thumb, although it is not entirely necessary. Various modifications of this procedure were used in instances of localized tendon paralysis, due to wounds of individual muscle bellies. War wounds pro- vide varied bizarre types of injuries which are ordinarily not seen.

We have operated upon twenty-two cases, of which fourteen were injuries of the com- plete radial nerve and two were injuries of the dorsal interosseous nerve. Six were localized injuries of the extensor tendons. Good results were obtained in all cases. Each patient left

FIG 6-A

FIG 7

Two cases of complete radial-nerve injury, showing range of motion of fingers and wrist before operation.

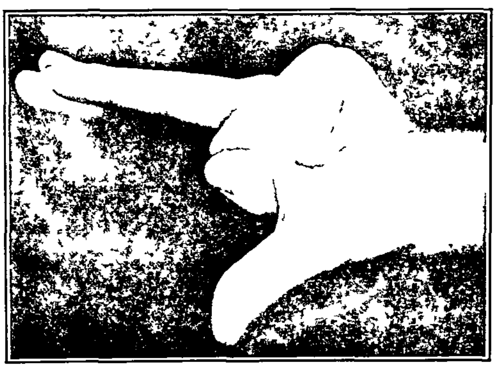

FIG. 6-B

FIG 8

Fig 6-B · Same case as Fig 6-A. Shows condition six weeks after operation

Fig. 8 Another patient; excellent result three and one-half weeks after operation is demonstrated

the Hospital with a functioning hand that had a strong, usable grip. Each case was reviewed by the Chief of the Orthopaedic Service and the Chief of the Neurosurgery Service, and was judged an excellent result. Dorsiflexion at the wrist was possible to 25 degrees above the straight line. Extension of all the fingers to completion was obtained at the interphalangeal joints. Complete extension at the metacarpophalangeal joints of the index finger, middle finger, ring finger, and little finger lacked approximately 15 degrees At the thumb, however, complete extension and abduction were accomplished.

The earlier cases, in which the right-angle incision was used, were delayed in their recovery by sloughing at the angle or by oedema of the dorsum of the hand. With the modified technique, this has not occurred thus far.

NOTE: The helpful suggestions and cooperation of Lieutenant Colonel Harry C. Blair, Chief of the Orthopaedic Branch, have made this study possible.

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BURSITIS IN THE REGION OF THE FIBULAR COLLATERAL LIGAMENT

BY I. E. HENDRYSON, M.D., DENVER, COLORADO

Voshell and Brantigan [1] have shown that bursitis in the region of the tibial collateral ligament is a distinct clinical entity. The author is not aware, however, of any report concerning a similar occurrence on the lateral aspect of the knee. In view of the frequency with which the lateral aspect of the knee is mentioned in connection with the diagnosis of "cyst of the lateral meniscus", the necessity for a description of bursitis in this region becomes apparent.

The purpose of this paper is to establish the identity of bursitis of the fibular collateral ligament as a definite clinical entity, to describe its pathology, and to consider its therapy.

HISTORY

The universal complaint associated with this bursitis is pain on the outer side of the knee. The pain is not characteristic, but descriptions of it range from "aching" and "burning" to "knifelike" and "stabbing" in quality. It is aggravated by exercise and, in most cases, is relieved by rest. In general, the duration of the discomfort is evaluated in terms of months rather than of days.

Causing almost as much concern to the patient has been the presence (in five of six cases) of a small swelling or "bunch", localized in the painful area on the outer side of the knee. The patient is not certain whether the mass appeared before or after the onset of pain, but he does know that the mass is slowly becoming larger and that it undergoes no remission.

It is difficult to assess the cause of his trouble, but the patient usually recalls a direct violence, a series of small injuries, or a repeated "banging" of the knee against some object, which, he feels, is of etiological significance. From a mechanical point of view, the knee bothers very little. Locking or blocking in the offending part is promptly denied. The patient may be aware of slight "insecurity", but no slipping has been noted.

Fig. 1

Low-power view of section of bursal mass, which at operation was lying under and a little anterior to the fibular collateral ligament. Several bursae and the adjacent groundwork are shown clearly.

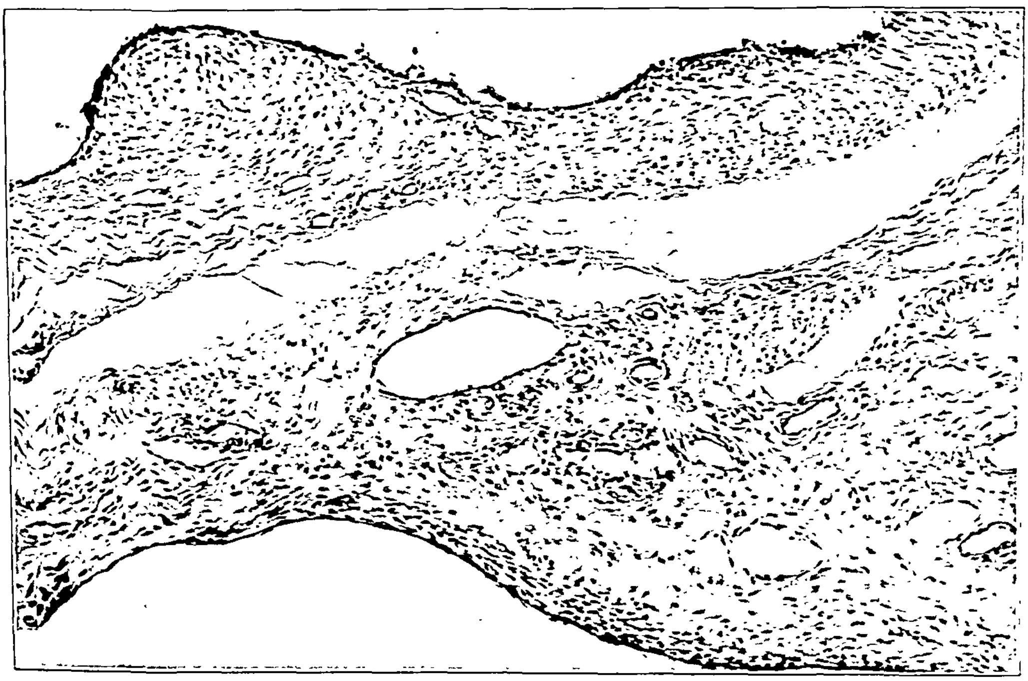


Fig. 2

High-power visualization of the area outlined in Fig. 1. Shows the structure of two of the larger bursae, and a small one in the center of the section.

TABLE I

CLINICAL DATA ON SIX CASES OF BURSITIS IN THE REGION OF THE FIBULAR COLLATERAL LIGAMENT

Patient	Knee	Symptoms and Signs	Duration of Symptoms	Etiology	Findings at Examination: Tenderness	Findings at Examination: Motion (*Degrees*)	Findings at Examination: Stability	Findings at Examination: Increase in Infrapatellar Circumference	Diagnosis: Before Operation	Diagnosis: After Operation	Findings at Operation	Recovery (*Days*)	Remarks
S.C., white male, aged 36	Right	Pain, marked on full extension	3 to 4 months	Insidious	Over mass	180 to 40	5 degrees lateral instability	2 to 2.5 centimeters	Cyst	Bursitis	Mass, 1.5 by 2 centimeters, seen through rent in ligament, posteriorly	23	
H.B., male negro, aged 21	Right	Pain; mass increasing in size	10 years	Football injury; repeated lesser injuries	Over mass	180 to 35	Good	2.5 centimeters	Cyst	Bursitis	Mass, 1.5 by 3 centimeters, anterior to and under ligament	41	
H.S., white male, aged 32	Right	Dull pain, radiating down leg	2 years	Basketball injury, direct trauma	Over mass	180 to 40	Good	2 centimeters	Bursitis	Bursitis	Mass, 1.5 by 1.75 centimeters, anterior to and under ligament	21	
H.C., white male, aged 20	Right	Pain; mass getting larger	6 to 7 months	Volleyball injury; repeated twisting of knee	Over mass	180 to 45	Good	2 centimeters	Bursitis	Bursitis	Mass, 1 by 1.75 centimeters, under ligament	25	
D.S., white male, aged 24	Left	Mass on outer side of knee, aching, and pain	2 to 3 weeks	Using knee to open truck door	Over mass	180 to 35	Good	1.5 centimeters	Bursitis (determined by aspiration)	Bursitis		16	Recovery with aspiration and support
B.Q., white male, aged 31	Left	Pain and aching in knee	4 months	Knee twisted while walking over rough ground	Over ligament at joint line (no mass present)	180 to 35	Good	None		Bursitis		12	2% novocaine injection, 3 times, at 4-day intervals; support

PHYSICAL EXAMINATION

Examination reveals signs which are located entirely on the outer aspect of the knee, in the region of the fibular collateral ligament. Inspection may reveal a well-localized swelling at the joint line, varying from 0.5 to 3 centimeters in size. There is no evidence of intra-articular effusion. Upon palpation, the mass may be semi-fluctuant or firm in character; it is not freely movable, and is tender to pressure. Its location may be directly over the fibular collateral ligament, or in juxtaposition to one of its edges. The overlying skin may be tense, but it does not exhibit the signs characteristic of an inflammatory process.

Tenderness is specific, and is confined to a small area at the joint line, or just inferior to it. In the cases in which no mass is evident, the tenderness is elicited by pressure on the ligament as it crosses the areas mentioned. Adduction of the extended tibia on the femur produces the pain. Internal rotation of the flexed limb will also produce the pain in most cases.

Stability and motion of the knee are usually not involved. Full extension may be voluntarily resisted, however, due to pain caused by pressure of the ligament on the bursal mass. One patient has been seen in whom the mass was large enough to affect the integrity of the ligament, causing 5 degrees of lateral instability.

DIAGNOSIS

Without surgery, it may be impossible to prove the diagnosis conclusively. With the characteristic history, signs localized in the area of the fibular collateral ligament, and pain upon adduction of the tibia, however, such a diagnosis is warranted. When aspiration of the fluid in the mass is possible, radiopaque material may be injected, so that the bursa will be visualized upon roentgenographic examination.

PATHOLOGICAL FINDINGS

Gross Appearance

The semifluctuant swelling may lie directly under the fibular collateral ligament, or it may project anteriorly or posteriorly to it. When seen in the central position, the fibers of the ligament are taut and show thinning. The mass lies outside the synovial membrane, has no intimate connection with the meniscus, and is encapsulated by its surrounding areolar elements. Upon removal, it feels rubbery to touch, as though it had fluid at its center. It is cut with about the same ease as dense fibrous tissue, and permits the escape of small amounts of clear, yellow, viscous fluid. The central portion consists of several sacs of various sizes, surrounded by considerable fibrous tissue, which gives the whole a multilocular appearance.

Microscopic Appearance

The striking feature is the presence of several punched-out areas, irregular in shape, variable in size, and containing no visible exudate. In the main, these areas are lined by a layer of flat irregular cells, characteristically bursal in nature; but in some cases they become multicellular, with pyknotic and ovoid nuclei.

The groundwork and the tissue adjacent to the bursae are composed primarily of fibroblasts, densely laid down, and orderly in appearance. A few scattered round cells are noted in this fibrous tissue and, rarely, a neutrophil is seen. There is an increase in the smaller vascular elements throughout.

In sections which contain, in addition, the lateral meniscus, there is no evidence of change in the inherent fibrocartilaginous structure, nor evidence of association of that structure in the pathological process described.

TREATMENT

Management of this condition is fundamentally the same as that of bursitis in other locations. Those patients revealing no mass respond favorably to injection with novocain support, and rest.

It is felt, however, that, in the majority of patients seeking treatment, some enlargement is present which requires attention. Aspiration of fluid from the mass is not uniformly successful. When it can be accomplished, subsequent rest and support of the knee are indicated; this often results in arrest of the condition.

The tendency for the pathological changes to involve more than one bursa leads to the conclusion that surgical removal of the entire mass is the treatment of choice. This procedure is not difficult, and requires only that protection of the fibular collateral ligament be assured. In those cases in which the mass underlies the central fibers of the ligament, adequate exposure is secured by making an incision longitudinal and parallel to them. Anterior or posterior enlargements may be approached by retraction of the ligament.

After operation, support is maintained (by means of sheet wadding and elastic-bandage dressing) throughout the period necessary for complete healing of the soft tissues. Early weight-bearing is permitted, and active motion is desirable only to the extent that it produces no undue pain. Quadriceps-setting exercises are instituted on the first day after operation, but other physiotherapy is not employed.

DISCUSSION

Although the pathological findings have been concerned wholly with cases in which a mass is present, it is reasonable to assume, from our general knowledge of the bursitides, that the condition exists and can produce symptoms without evidence of a visible or palpable enlargement. Such a case has been included in Table I, but the diagnosis has not been definitely proved by microscopic examination.

Although one bursa may be responsible for the gross appearance of the mass, it is evident microscopically that others of smaller size are involved in the same process. More often, multiple bursae are equally affected, giving rise to a multilocular enlargement. This fact explains the difficulty encountered in attempts at aspiration, and also points to the possibility of future recurrence.

The similarity of the condition to cystic degeneration of the meniscus emphasizes the need for care in dissecting out the mass at the time of operation. In bursitis, no involvement of the cartilage is observed and meniscectomy is unnecessary. It is evident that cartilages have been sacrificed which were free from any pathological condition other than that of lying adjacent to a bursa in the region of the fibular collateral ligament.

1. Voshell, A. F., and Brantigan, O. C.: Bursitis in the Region of the Tibial Collateral Ligament. J. Bone and Joint Surg., **26**: 793–798, Oct. 1944.

AIR ARTHROGRAPHY AS AN AID TO DIAGNOSIS OF LESIONS OF THE MENISCI OF THE KNEE JOINT

BY SQUADRON LEADER E. W. SOMERVILLE

Royal Air Force Volunteer Reserve

Since the outset of World War II, many men have exchanged their comparatively sedentary ways of civilian life for the more energetic life in the Services, with the result that the number of minor injuries has increased considerably. The knee joint is one of the regions most frequently affected, and injuries vary from simple sprains to the more extensive lesions in which the structures of the joint are torn or fractured.

Sometimes the clinical differentiation of these lesions is difficult. Thus in some cases, the correct diagnosis cannot be made until arthrotomy has been performed. For this reason, attempts have been made in the past to devise methods to aid or to reinforce the clinical examination.

Foremost among these methods has been the use of roentgenograms. First a contrast medium is injected, which may be either positive or negative, and which outlines the soft structures of the joint. Various media, such as oxygen, air, and uroselectan, have been used, and many different positions for taking effective roentgenograms have been advocated by Kleinberg, Quaintance, Cullen and Chance, Hauch, and Somerville.

A technique of outlining the menisci, without injection of a contrast medium, has been described by Dittmar, by Rubin, and by Evans. This method depends upon the phenomenon that, when the articular surfaces of a joint are forcibly separated, a thin line of translucency appears, which outlines the true joint space. If the separation of the articular surfaces is maintained, the translucency lasts for as long as ten minutes. Any fluid in the joint makes this translucency impossible. It is believed that the translucency is due to the extraction of gases from the tissues, as a result of the negative pressure. In the case of the knee joint, the separation of the articular surfaces can be obtained by forcibly adducting or abducting the tibia on the femur.

In the present series, 331 knees have been examined by air arthrography. The technique employed combines the more important features described by previous workers. While the basis of the technique has remained the same in all cases, many variations in detail have been tried and improvements have been made from time to time.

TECHNIQUE

In the earlier cases in the series, air arthrography was done separately from the clinical examination and the examination under anaesthesia. In subsequent cases, the following routine was found to be more satisfactory:

After a skin preparation of forty-eight hours, the patient is taken to the operating theater, where the clinical examination is repeated and the straight roentgenograms are reviewed. Pentothal-sodium anaesthesia is used; the knee is examined; and any abnormalities are noted. The towels used in preparation are removed, and the skin is cleaned with alcohol. The knee is then filled with air, which is injected through a needle of medium bore, inserted in the outer side of the joint at a level with the lower pole of the patella. Prior to injection, the air is filtered through cotton wool; a twenty-cubic-centimeter syringe with a two-way cock is used (Fig. 1).

After the needle has been removed, the puncture wound is sealed with mastisol, and a dressing is applied. Towels are reapplied and are fixed securely so that they will not slip with subsequent manipulation. Should a lesion be found, the patient will be ready for operation on the following day. He is then transferred to the X-ray Department.

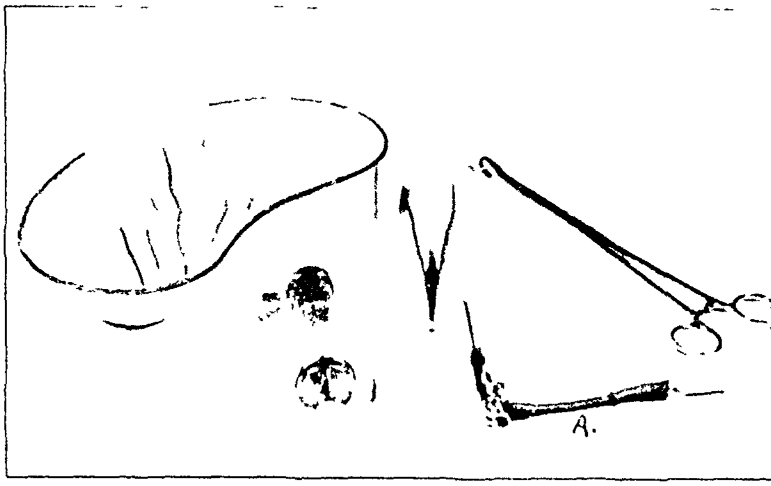


FIG. 1
Instruments used for injection of air into knee joint. *A*: Two-way cock and filter of cotton wool.

FIG. 2
Curved stand, showing cassette in position.

Roentgenography

The apparatus employed in taking the roentgenograms consists of a stand, six inches high, with a curved top, into which a curved cassette, eight inches by ten inches, can be inserted (Fig. 2). A sinus cone, sixteen inches in length by two and one-half inches in diameter, is used; the distance from tube to film is approximately twenty-four inches. Fifty-five milliamperes, forty-five kilovolts, and 0.4 second of exposure are given.

A crepe bandage is applied firmly above the knee in order to express the air from the suprapatellar pouch and to raise the intrajoint pressure temporarily. By this technique, a smaller quantity of air can be used, with greater advantage.

Certain routine views are taken first in all cases, and later other views are taken which may be suitable in a particular case. The routine views have been labeled M.1,

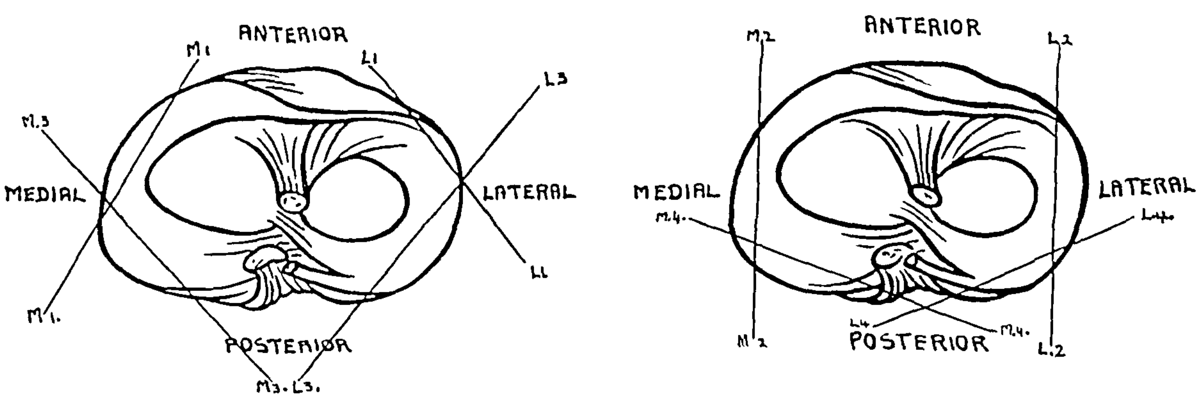


FIG. 3
The four routine views of each meniscus.

M.2, M.3, M.4 (medial) and L.1, L.2, L.3, L.4 (lateral); they are tangential views of the menisci (Fig. 3). Anteroposterior and lateral roentgenograms of the whole joint are also taken; and, in certain cases, axial views of the patella.

Views 1 to 3, medial and lateral, are taken with the knee slightly flexed over the curved stand at an angle of approximately 150 degrees. The cone and tube are adjusted so that the central ray is focused on the center of the stand at the level of the knee joint, with the cone at an angle of 80 degrees to the horizontal. The operator extends the patient's knee slightly until the tibia and the cone are at right angles to each other, at which time the central ray should pass through the side of the joint being examined. By

Fig. 4

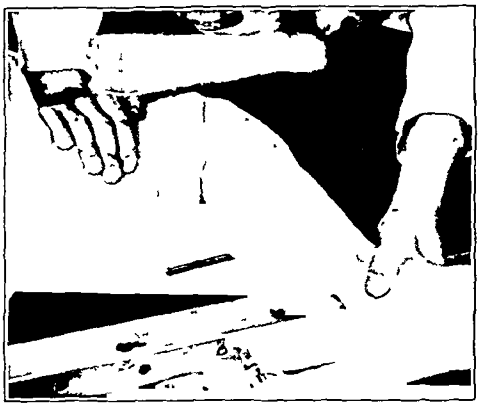


Fig. 5

Fig. 4: Shows position and technique for taking routine views. Note crepe bandage firmly applied above knee. View M.2 is being taken. The tibia is being abducted on the femur during the exposure, thus widening the inner side of the joint.

Fig. 5: Technique employed in taking Views M.4 and L 4. M.4 is being taken. The knee is flexed to 90 degrees, while the thigh is steadied with one hand and the tibia is internally rotated with the other hand.

this means, all the views may be taken by simply moving the knee and rotating it to whichever side is necessary, with no further adjustment to the cone or the stand except for the insertion of fresh cassettes. *Two views can be obtained on each film; if three* cassettes are used, the entire examination can be completed in about two minutes.

Fig. 6

Technique employed in taking "sky-line" view of the patella.

The position of the joint is localized by palpation; with practice, this method has proved sufficiently accurate. The use of a fluorescent screen to outline the joint exactly is time-consuming and unnecessary.

While each view is being taken, the tibia is either abducted or adducted forcibly on the femur, in order to widen the side of the joint being examined (Fig. 4).

If the knee is in full *extension and the lateral ligaments are intact, it is impossible to widen either side of the joint; but, if the knee is slightly flexed, the lateral ligaments are* relaxed, and even in the tightest joint a certain amount of widening can be obtained. This procedure proved satisfactory in Views 1 to 3 (medial and lateral). Occasionally, however, a lesion in the posterior part of the meniscus will not be seen by this method, but may be demonstrated by a different technique.

For this purpose, the patient is turned on his side and the knee is flexed to an angle of 90 degrees with a flat cassette, six inches by eight inches, beneath it. The cone is brought down to the knee and is focused so that the central ray will pass through the back of the joint. The tibia is rotated medially or laterally on the femur (Fig. 5), so that either the medial or the lateral tibial condyle will be posterior, and will therefore be outlined clearly, with the respective meniscus on the posterosuperior aspect.

Since the conclusion of this series, a technique has been devised for outlining the articular cartilage of the patella and the adjacent articular cartilage of the femoral condyles. The knee is filled with considerably more air than is used for the other views. The compression bandage is applied above the knee, and the knee is flexed over the curved stand to the greatest extent possible without obliterating the patellar tap. With an

ordinary dental occlusal film pressed hard into the patellar ligament, immediately above the tibial tuberosity, a roentgenogram is taken, as shown in Figure 6.

INTERPRETATION OF ROENTGENOGRAMS

Upon examination of a straight roentgenogram of a knee containing air, the following soft-tissue structures may be seen: both menisci, the cruciate ligaments, the articular cartilage, and a retropatellar pad of fat. There is a clear outline of the joint itself and of the communicating bursae. The bony detail also appears better defined than is usually seen in roentgenograms of joints not containing air. Unfortunately, many of these shadows overlap and produce a misleading appearance. On the outer side of the joint, the shadows are further complicated by the presence of the tendon of popliteus, which separates the lateral meniscus from the fibular collateral ligament. The synovial sheath of this tendon is filled with air. The number of misleading shadows is considerably reduced—though, unfortunately, not completely excluded—by the technique previously described of widening the joint on one side.

Normal Appearance of Menisci

The normal appearance of the menisci is shown in Figures 7 and 8. These diagrams show the average shape and relative size of both menisci, but considerable variation may be seen without a significant abnormality being present. In each view, the meniscus is seen in cross section.

Medial Meniscus: The medial meniscus is firmly adherent to the capsule and to the tibial collateral ligament peripherally in its whole length. In View M.1, the meniscus is small and triangular in shape and it does not

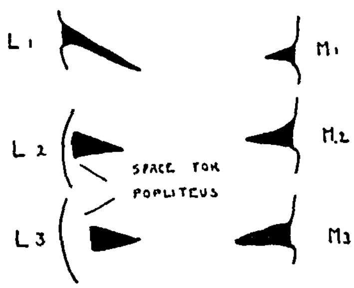


FIG. 7

Diagrammatic representation of six routine views of the menisci, as seen by air arthrography. Each view is taken separately.

FIG. 8

Diagrammatic representation of View M.4. The meniscus can be seen, lying on the posterior lip of the medial tibial condyle.

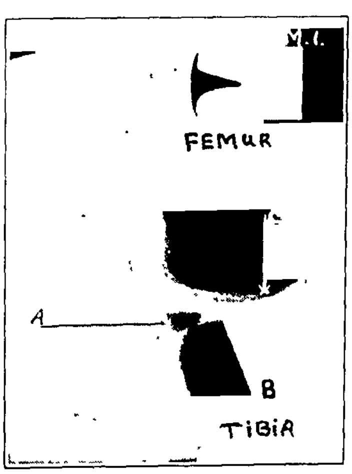


FIG. 9

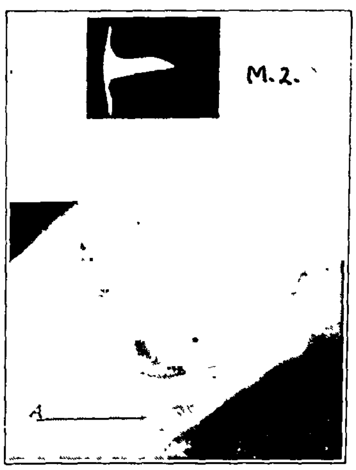


FIG. 10

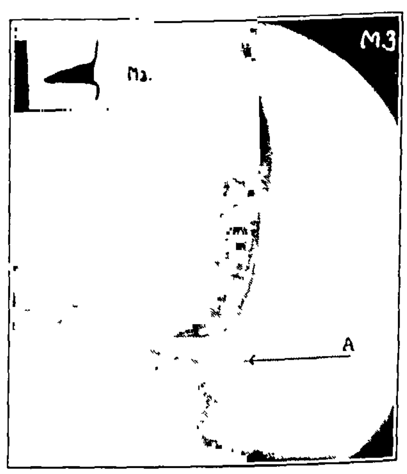


FIG. 11

Fig. 9: View M.1, showing a normal medial meniscus at its anterior end. *A*, Meniscus; *B*, air in joint; *C*, femoral articular cartilage. Inset shows average size and shape of meniscus.

Fig. 10: View M.2, showing normal medial meniscus at its mid-point. *A*, Medial meniscus. Inset shows differently shaped meniscus which is often seen.

Fig. 11: View M.3, showing normal medial meniscus in its posterior portion. *A*, Medial meniscus, which is a little longer than usual. Inset shows more usual size.

protrude far into the joint. As examination continues posteriorly, the triangular shape of the meniscus is maintained, but its size is increased considerably in Views M.2 and M.3 (Figs. 9, 10, and 11), and it can be seen protruding farther between the articular surfaces.

In M.4, the meniscus can be seen lying on the posterosuperior aspect of the tibial condyle, with its peripheral attachment sweeping away posteriorly to form a pouch filled with air (Fig. 12). In a normal knee, there is no break in the smooth line. A second pouch filled with air may sometimes be seen beneath the peripheral attachment of the meniscus, lying between it and the

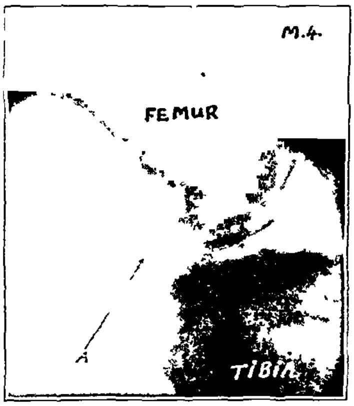


Fig. 12

Fig. 12: View M.4, showing normal medial meniscus (*A*), lying on posterior lip of medial tibial condyle.

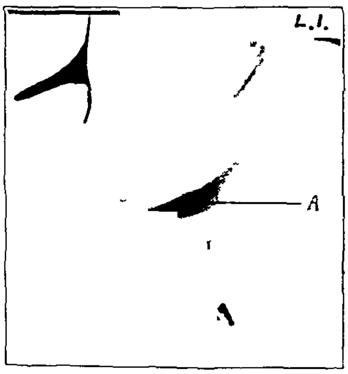


Fig. 13

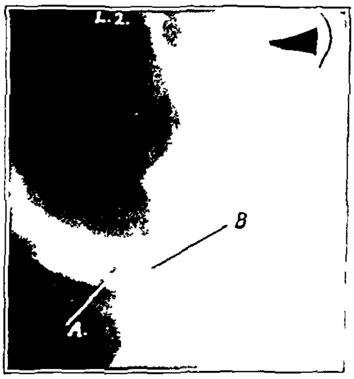


Fig 14

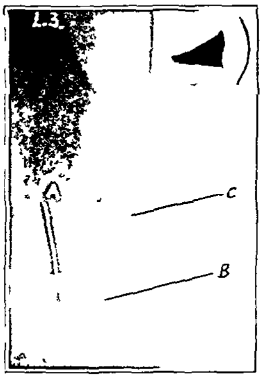


Fig 15

Fig. 13: View L.1, showing normal lateral meniscus in its anterior portion (*A*). Inset shows normal shape and size of meniscus.

Fig. 14: View L.2, showing normal lateral meniscus at mid-point. *A*, Meniscus; *B*, small separation produced by tendon of popliteus Inset shows normal arrangement.

Fig. 15: View L 3, showing normal lateral meniscus in posterior portion. *A*, Meniscus; *B*, normal separation; *C*, sesamoid bone in gastrocnemius.

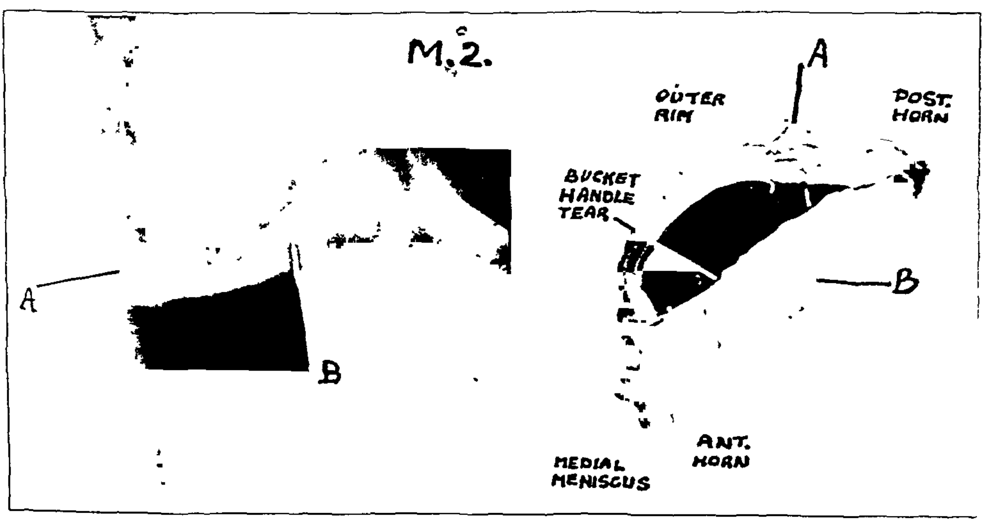


Fig. 16-A Fig 16-B

Fig. 16-A: Arthrogram showing bucket-handle lesion of medial meniscus. *A*, Outer rim; *B*, displaced bucket handle. Fig. 16-B: Shows meniscus subsequently excised.

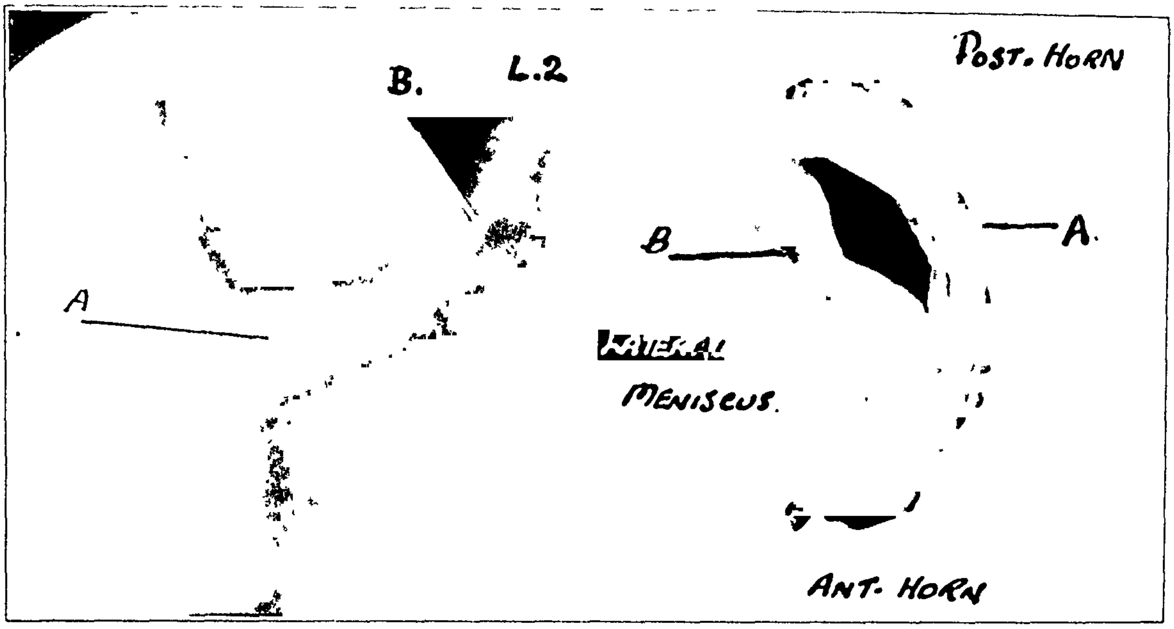


FIG. 17-A FIG. 17-B

Fig. 17-A: Arthrogram showing bucket-handle tear of lateral meniscus. *A*, Outer rim; *B*, displaced bucket handle.

Fig. 17-B: Shows meniscus after excision.

tibia (Fig. 29). This is usually small in size; but, if it is large, it may indicate a loosely attached meniscus. These appearances suggest strongly that, when the normal knee is in a position of flexion, there is a tendency for the meniscus to be drawn out of the back of the joint.

Lateral Meniscus: The lateral meniscus is entirely different from the medial meniscus in shape and size. Anteriorly, in L.1 it is long and thin, extending from the capsule, with which it is continuous, well into the joint, and it is raised from the tibia (Fig. 13). As the examination continues posteriorly, it becomes more triangular in shape. In L.2 it may be

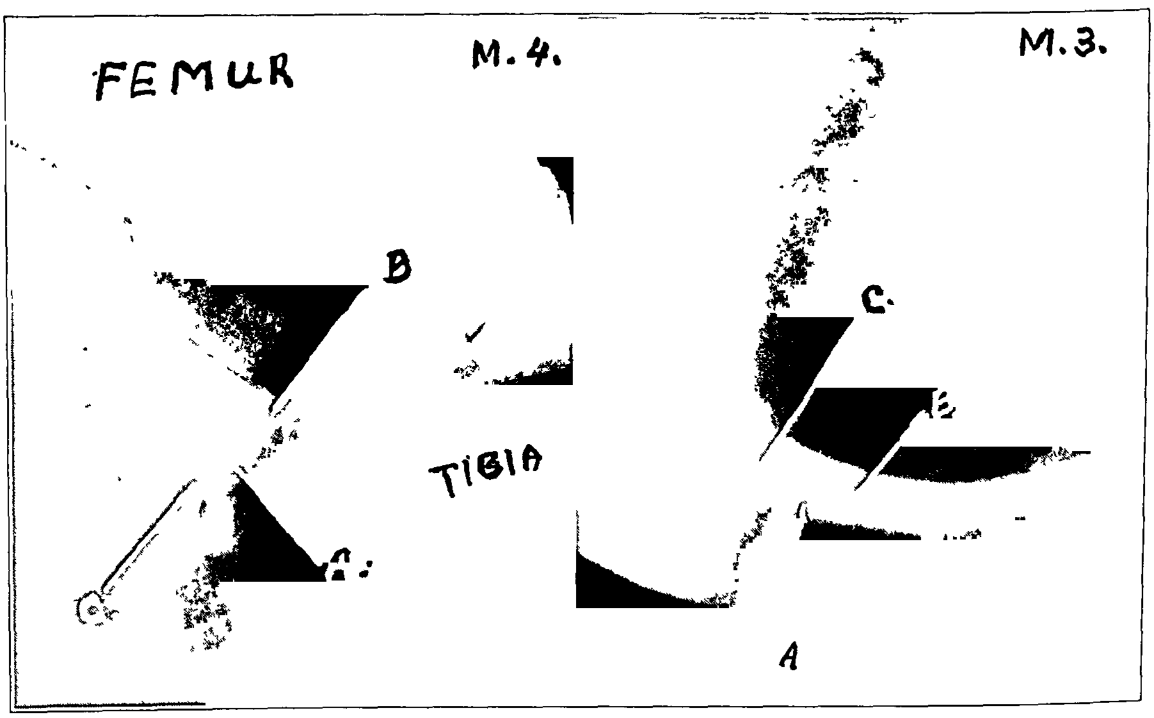


FIG. 18-A FIG. 18-B

Tear of posterior horn of medial meniscus, as shown in Views M.4 and M.3. *A*, Tear of posterior horn; *B*, displaced portion of meniscus; *C*, peripheral rim.

either continuous with the capsule, or, as is more frequently the case, slightly separated from it by the tendon of popliteus (Fig. 14). In L.3 it is always separated peripherally from the capsule by a wide gap, which again is produced by the tendon of popliteus. This peripheral separation should not be mistaken for a tear. It is always present, but is usually not wider than three-eighths of an inch. Its presence makes the interpretation of lesions of the lateral meniscus more difficult than those of the medial meniscus (Fig. 15).

View L.4 is not very satisfactory, and present experience indicates that it would be unwise to place much reliance upon it. The appearance is similar to that seen in M.4, but it is not so clear and the posterior part of the separation produced by *the tendon of popliteus may be very misleading.*

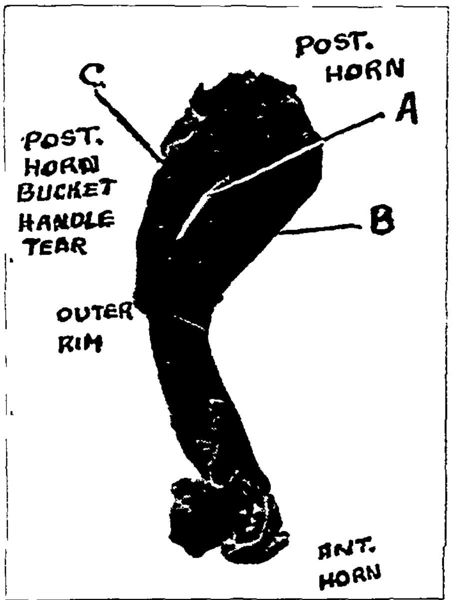


FIG. 18-C
Shows the meniscus itself.

Lesions of Menisci

It is usually possible to make a definite diagnosis from an arthrogram as to what type of tear is present in a meniscus, but in certain cases it is only possible to say that a lesion is present. This is particularly true of the lateral meniscus.

Bucket-Handle Tears: These lesions can be diagnosed with considerable accuracy, both in the medial and lateral menisci, particularly if the bucket-handle portion is displaced into the intercondylar notch. If, however, the displaced portion is very small, as is occasionally the case, it may not be possible to differentiate it from the shadows of the cruciate ligaments in the intercondylar notch. It is safer, therefore, to diagnose this lesion by the presence of a small, irregular outer rim, and to ignore the shadows in the center of the joint. If the bucket handle is not displaced, a definite split can be seen in the cartilage substance itself (Figs. 16-A, 16-B, 17-A, and 17-B).

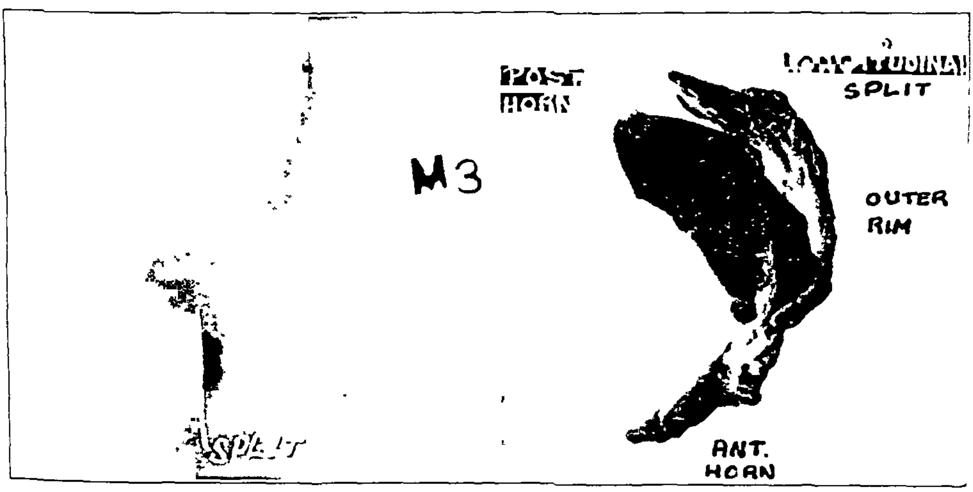


FIG. 19-A FIG. 19-B

Fig. 19-A: Arthrogram showing irregular tear of posterior horn of medial meniscus, as seen in View M.3.

Fig. 19-B: Excised meniscus.

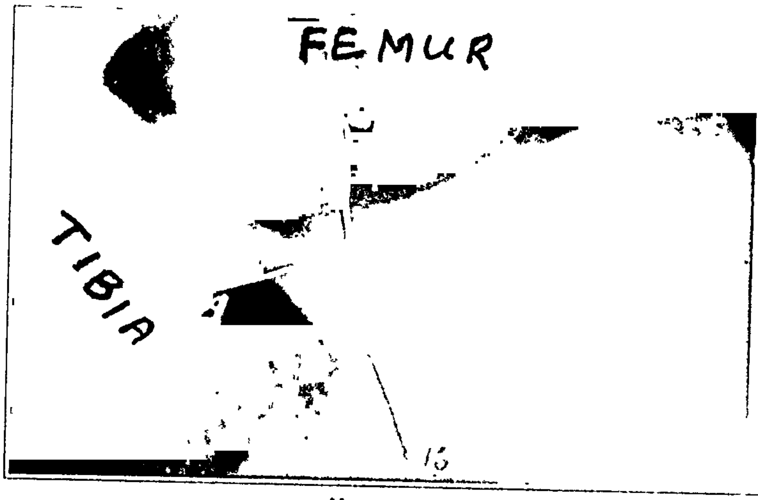


FIG. 20-A

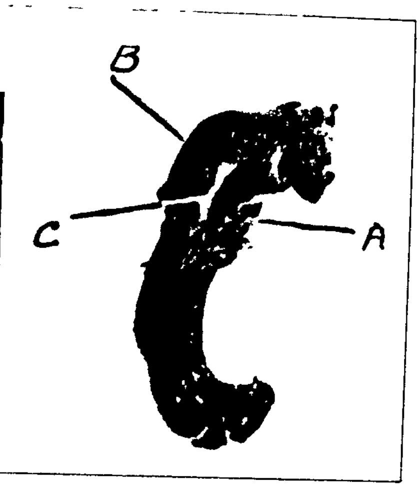


FIG. 20-B

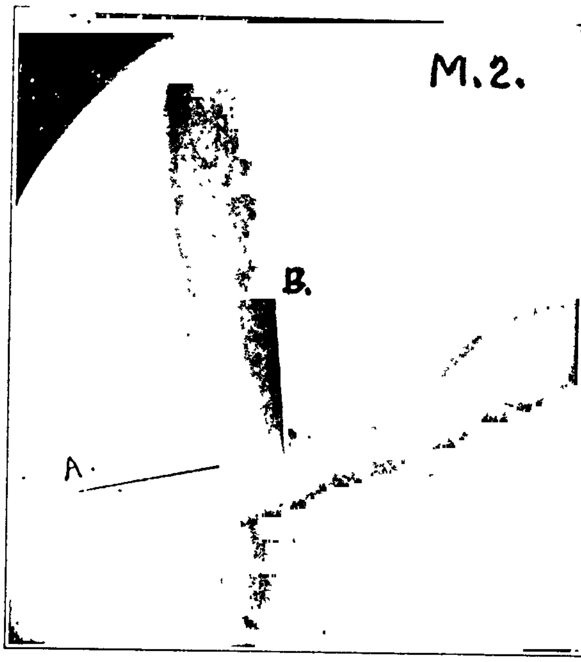


FIG. 21-A

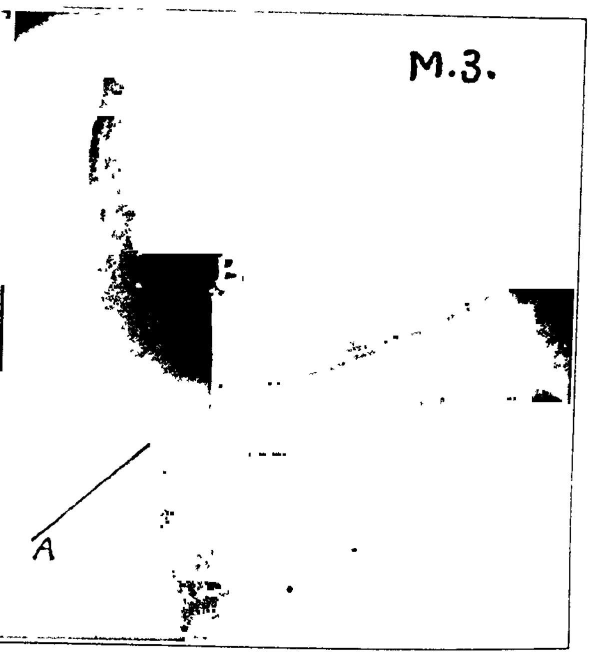


FIG. 21-B

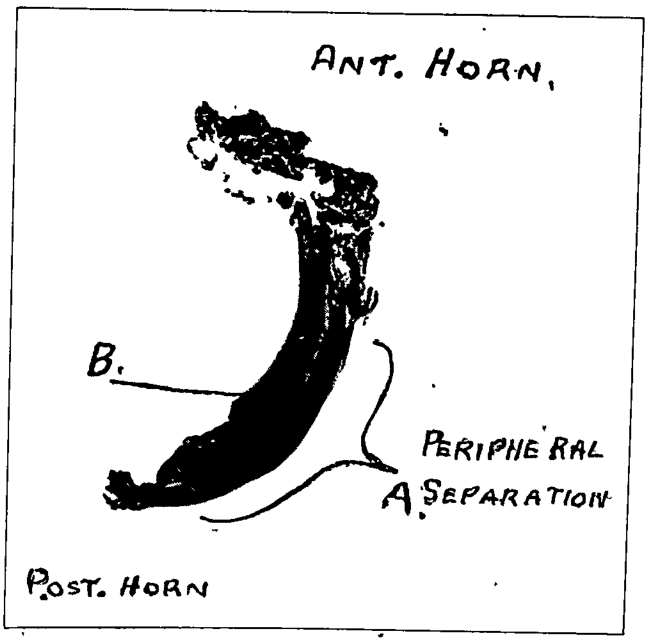


FIG. 21-C

Fig. 20-A: Tear of posterior horn; seen in View M.4, but not in other views.

Fig. 20-B: Excised meniscus. *A*, Displaced portion of meniscus; *B*, peripheral rim; *C*, small tear.

Figs. 21-A and 21-B: Peripheral tear of medial meniscus, as seen in Views M.2 and M.3. *A*, Peripheral tear. No outer rim seen in M.2, but faint rim is seen in M.3. *B*, Displaced portion of meniscus.

Fig. 21-C: Excised meniscus.

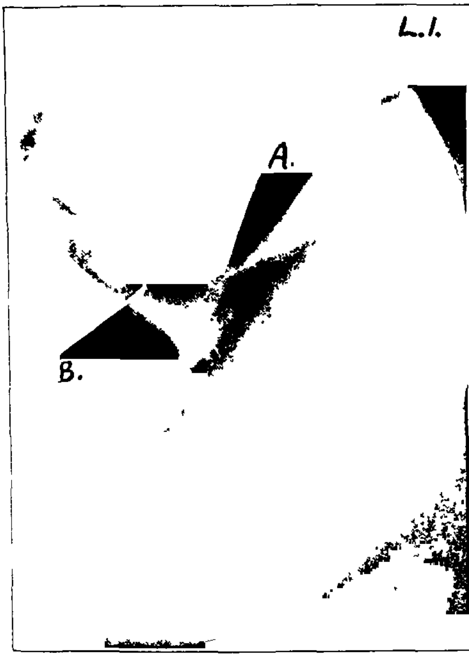


Fig. 22-A

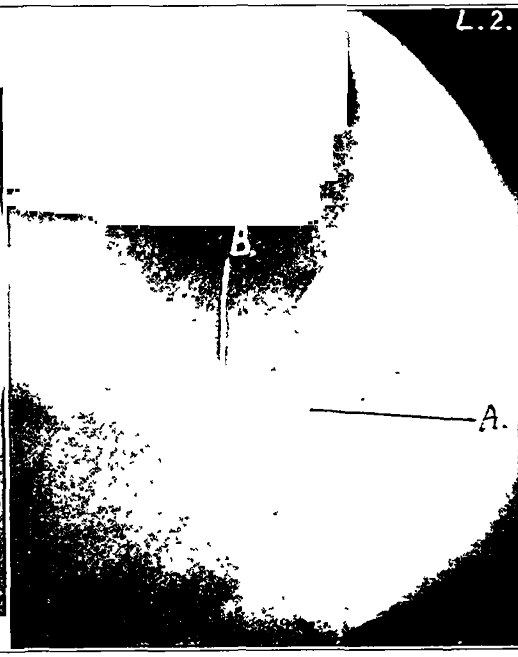


Fig. 22-B

Figs. 22-A and 22-B: Peripheral tear of lateral meniscus, as seen in Views L.1 and L.2, resulting in widening and lengthening of the normal separation, due to tendon of popliteus. *A*, Separation; *B*, meniscus.

Fig. 22-C: Excised meniscus.

Fig. 23-A: Arthrogram in View M.3, showing tear near the periphery of a medial meniscus.

Fig. 23-B: Excised meniscus.

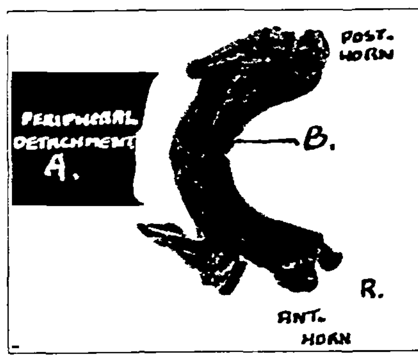


Fig. 22-C

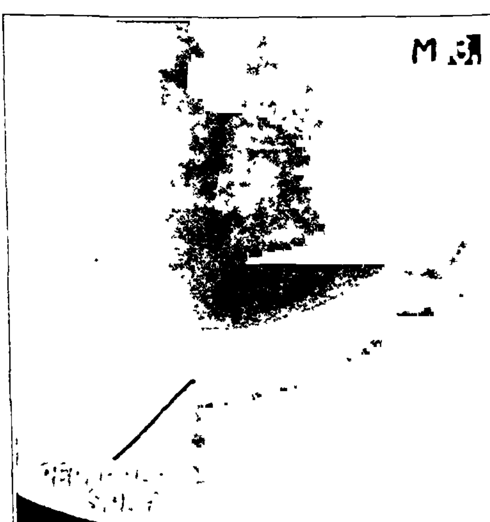


Fig. 23-A

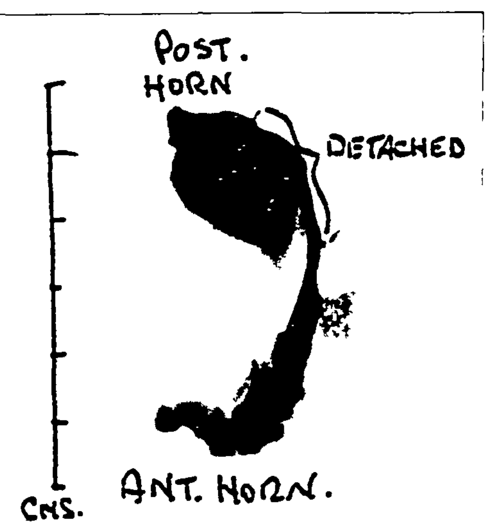
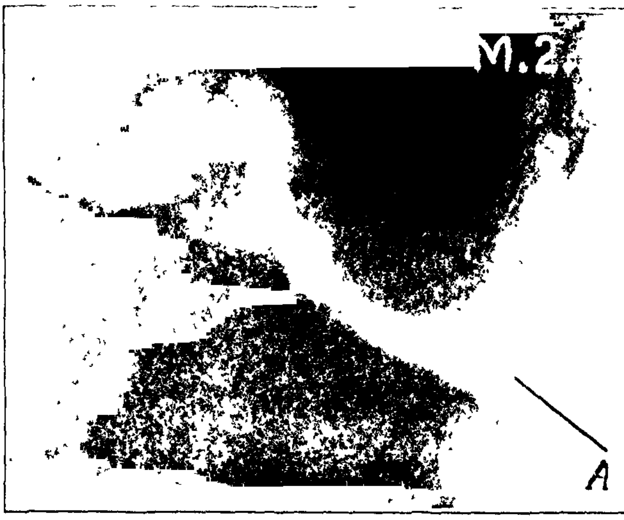


Fig. 23-B



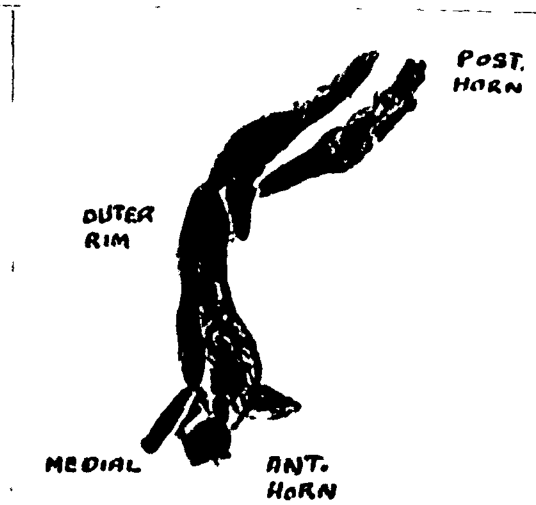


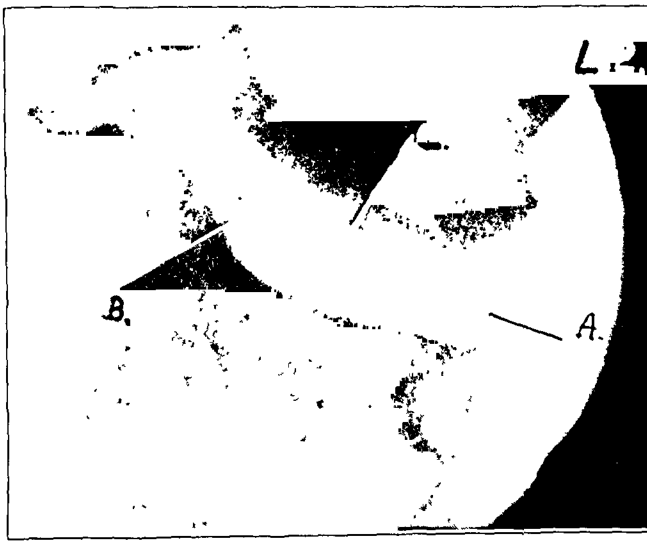
FIG. 24-A FIG. 24-B

Fig. 24-A: Arthrogram in View M.2 shows severely contused meniscus. *A*, Contused meniscus.

Fig. 24-B: Excised meniscus. The apparent splits in the meniscus are due to the fact that it was removed in several pieces, through two incisions.

Lesions of the Anterior and Posterior Horns: Lesions of the posterior horn are se in Views M.3 and L.3, and may also be seen in M.4; View L.4 is unreliable. When t lesion is in the medial meniscus, an obvious split can be seen, which may appear to either in the meniscus itself or at its peripheral attachment. In M.4, the lesion is seen the posterior lip of the tibial condyle.

Peripheral tears of the lateral meniscus consist of enlargement, either forward backward, of the separation which is normally produced by the tendon of popliteus. Th permits undue mobility of the meniscus, which can be seen displaced toward the center the joint, lying between the condyles of the femur and the tibia. This results in wideni of the normal peripheral separation. If this separation appears to be wider than one-ha inch, a lesion is probably present (Figs. 22-A and 22-B).



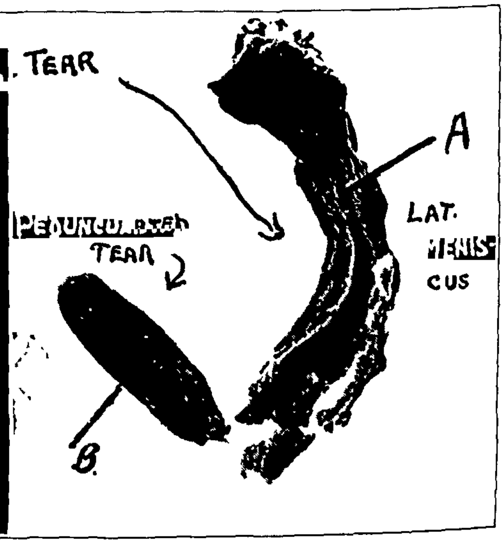


FIG. 25-A FIG. 25-B

Arthrogram, in View L.2, shows severely contused lateral meniscus, with large anterior tag. *A*, Contused rim of meniscus, containing small but definite split; *B*, large anterior tag displaced and lying in intercondylar notch; *C*, definite area of erosion and thinning of articular cartilage of femur, subsequently confirmed at arthrotomy.

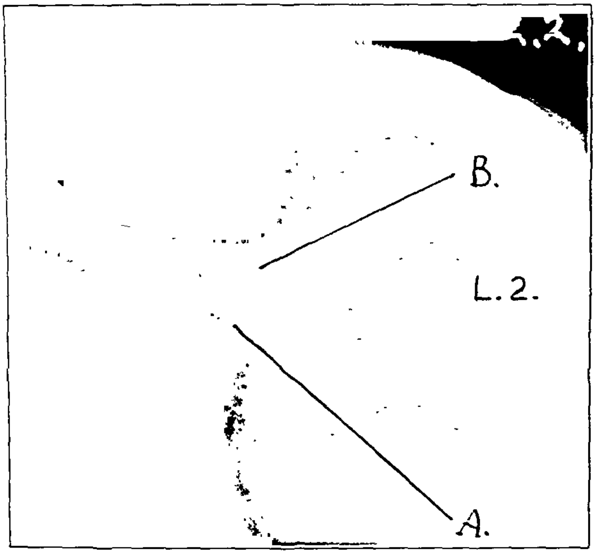


FIG. 26-A

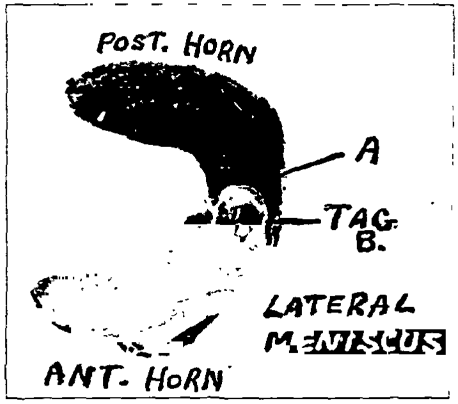


FIG. 26-B

Fig. 26-A: Arthrogram in View L.2, showin a horizontal tear of the lateral meniscus. *A*, Main part of meniscus; *B*, tag on upper surface. The tear can be seen between *A* and *B*.
Fig. 26-B: Excised meniscus.

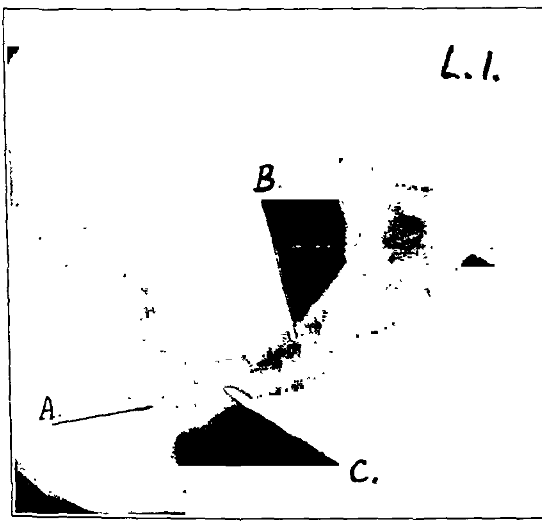


FIG. 27-A

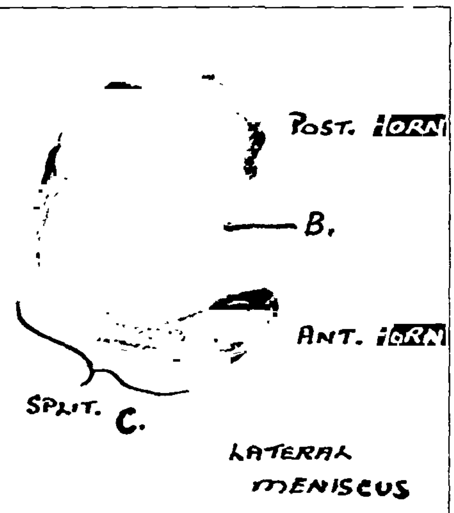


FIG. 27-B

Fig. 27-A: Arthrogram in View L.1, showing tear at periphery of lateral discoid meniscus. *A*, Peripheral attachment; *B*, main body of meniscus; *C*, peripheral tear.
Fig. 27-B: Excised meniscus.

Miscellaneous Lesions: Other types of lesions of the menisci should be considered.

1. *Persistent Remnants of Posterior Horn*: Pieces of menisci of various sizes may be seen, usually in the views of the posterior horn, following incomplete meniscectomy. The size of the remnant is always exaggerated on the arthrogram.

2. *Contused Menisci* (Figs. 24-A and 24-B): This type of damaged meniscus has perhaps not received sufficient recognition. The clinical picture is often rather indefinite. Locking and giving way of the knee are unusual. In the arthrogram, the outline of the meniscus is rounded and irregular and appears to be smaller than usual. The appearance often suggests that a bucket-handle lesion may be present, with the displaced bucket handle concealed by the shadows in the intercondylar notch.

3. *Tag Lesions*: Pedunculated tags result from old longitudinal or oblique tears, in

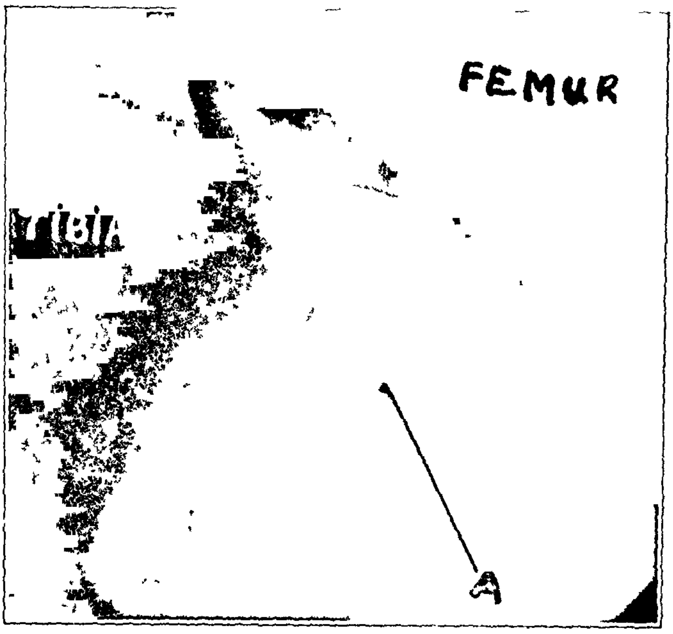


Fig. 28

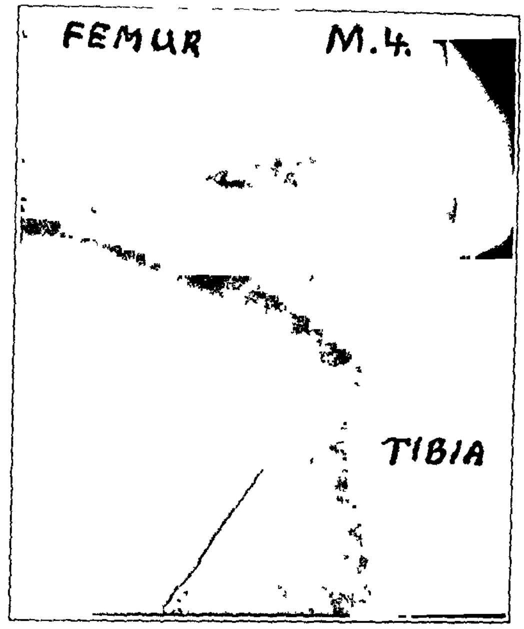


Fig. 29

Fig. 28: Arthrogram in View M.1, showing "hypermobile" medial meniscus. *A*, The long lax synovial attachment of the meniscus.

Fig. 29: Arthrogram showing lesser degree of hypermobility of medial meniscus, as seen in View M.4. *A*, The medial meniscus is drawn out of back of joint more than is customary. A pouch can be seen above and below it. Arthrotomy was not performed in this case.

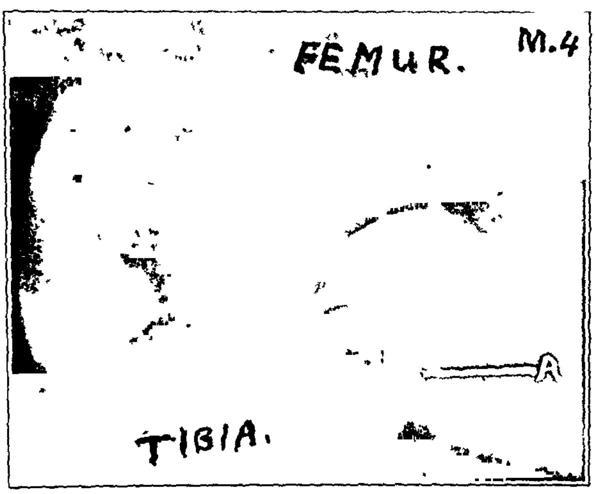


Fig. 30

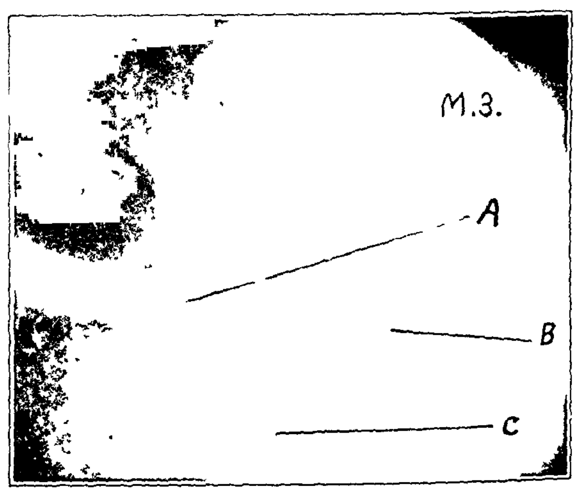


Fig. 31

Fig. 30: Arthrogram showing View M.4, following meniscectomy. *A*, Small rim remains.

Fig. 31: Arthrogram in View M 3, showing lesion of medial meniscus and semimembranosus bursa, containing loose body. *A*, Damaged medial meniscus; *B*, loose body; *C*, semimembranosus bursa. Arthrotomy was not performed in this case.

which one end of the tear has become separated and secondary deformation of the tag has occurred. If the tear is oblique, a horizontal split is seen in the arthrogram. This lesion appears to occur more frequently in the lateral meniscus. Loose tags arising from the body of the meniscus, however, are more common on the medial side than on the lateral side. The tag itself may not be seen clearly, as it tends to lie across the joint, overlapped by the anterior and posterior articular margins of the tibia. The outline of the meniscus itself is reduced in size and is irregular (Figs. 25-A and 26-A).

4. *Discoid Menisci*: Because the center of the discoid meniscus is very thin, it does not throw a clear shadow and the appearance may suggest that a large meniscus is present with a displaced bucket-handle lesion. Sometimes, however, a definite split can be seen (Fig. 27-A).

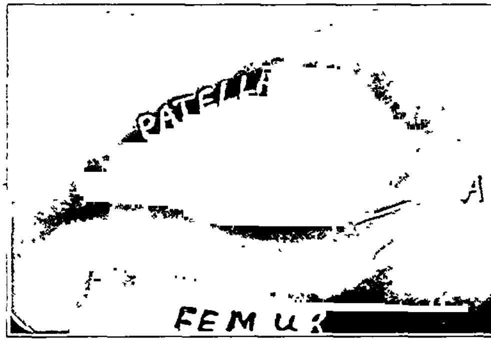


FIG. 32

"Skyline" view of patella, showing outline of articular cartilages (*A*), with air between.

5. *"Hypermobile" Lesions*: That hypermobility of a meniscus exists to a degree sufficient to cause symptoms has long been challenged. In the present series, true hypermobility was demonstrated (and proved by operation) on only one occasion. In this case the posterior horn appeared to be detached from the tibial spine. The arthrogram in View M.4 shows the posterior part of the meniscus drawn well out of the joint, although how much of this is really meniscus and how much is synovial membrane is difficult to tell (Fig. 28). At arthrotomy, it could be seen quite definitely that, when the knee was flexed, the meniscus was drawn out of the back of the joint; and, when the joint was extended, the meniscus returned between the articular surfaces. In doing this, it caught on the posterior lip of the tibia and resumed its normal position with an audible click. The meniscus itself was undamaged. Although it is not intended in this communication to discuss the results of treatment, it is interesting that this patient's symptoms were cured by meniscectomy.

In one other patient a similar appearance was obtained in M.4, but the degree of mobility was much less marked (Fig. 29). The meniscus can be seen drawn out of the back of the joint more than is usually the case; there is a pouch of air above and below it. Unfortunately, arthrotomy could not be undertaken in this case.

Other Joint Lesions

Lesions other than those of the menisci can be demonstrated with less accuracy. They are as follows:

Erosion of Articular Cartilage: It is possible to demonstrate only extensive and deep erosion of the articular cartilage. Attempts to demonstrate erosion of the articular surface of the patella have proved more promising with the technique previously described. These results, however, are not included in the present series (Fig. 32).

Loose Bodies: In the present series only two cases of non-osseous loose bodies were shown; both of these were of large size. Small loose bodies, subsequently found in conjunc-

TABLE I

RESULTS IN CASES IN WHICH A LESION WAS DIAGNOSED

Diagnosis by Arthrogram	Number of Knees	Number of Arthrotomies	Number Proved Correct by Arthrotomy	Pathological Findings in Cases of Incorrect Arthrographic Diagnosis: Number	Pathological Findings
Tears of medial meniscus	146	138	130	3	No lesion
				2	Synovial tag
				1	No lesion as diagnosed, but lesion found in other meniscus
				1	Loose body
				1	Tear of anterior cruciate ligament
Tears of lateral meniscus	45	43	41	1	No lesion
				1	Synovial tag
Tears of both menisci	21	20	20		
Other lesions	4	4	4		
Totals	216	205	195	10	

tion with other lesions at arthrotomy, were not visible on the roentgenograms. In several knees, loose bodies were demonstrated on the arthrogram when they were not seen on the straight anteroposterior and lateral views, but this was probably due to the number of views taken. It is doubtful whether arthrography helps in the discovery of loose bodies.

Osteochondritis Dissecans: Although this lesion can be seen more distinctly with air in the joint, in all cases the diagnosis had already been established by straight roentgenograms.

Semimembranosus Bursa: Following the injection of air into the joint, the bursa can frequently be palpated clinically and is found in a number of knees in which its presence had caused no symptoms. In one knee, a semimembranosus bursa was seen, which contained a loose body (Fig. 31).

RESULTS

In the present series, 331 knees have been examined by air arthrography. A variety of lesions have been demonstrated,—some with ease and some with great difficulty. At the beginning of the series, the diagnosis was less accurate than it was later, owing to lack of experience in interpretation, which led to a proportion of the errors. No selection of cases was made.

Of the 331 knees which have been examined, lesions were diagnosed in 216 and were not demonstrated in 108. There were seven failures.

Of the 108 knees in which no lesion was found, the clinical signs and history in twenty-one were such that the negative diagnosis was considered to be in doubt and an arthrotomy was performed. Of these cases, sixteen were found to have no lesion and five to have a lesion of some type.

Table I presents the results in the 216 knees in which a lesion was diagnosed. Two hundred and five came to operation and, of these, 195 were found to have lesions, as diagnosed. There were 130 lesions of the medial meniscus and forty-one lesions of the lateral meniscus. There were twenty double lesions and four other lesions, such as osteochondritis dissecans.

Of the ten in which a positive diagnosis was made incorrectly, four had no lesions, three had synovial tags and hypertrophied retropatellar pads of fat, one had a loose body, one had a torn anterior cruciate ligament, and one had a lesion in the meniscus opposite that in which it was diagnosed.

In twenty-one knees there were double lesions, twenty of which came to operation. In twelve of these, the second lesion was unsuspected before the arthrogram was made.

Excluding the seven failures, therefore, there was an apparent inaccuracy of fifteen (ten errors of commission and five of omission) in 324 knees, or an inaccuracy of 4.5 per cent. This figure may not be exact, as there is no certain way of knowing how many of the negative diagnoses were correct, or whether the diagnoses were accurate in the eleven patients upon whom operation was not carried out.

All but one of the seven failures were due to the presence of fluid in the joint. It would appear that an excess of fluid is a contra-indication to air arthrography. Aspiration of the fluid, before the injection of air, is insufficient. Turning the knee, when taking the views, so that the part of the meniscus being x-rayed is uppermost and therefore away from the fluid, is not entirely satisfactory. Synovial fluid is viscous and tends to cling to the menisci, thus obscuring their outlines in a certain number of cases. It is therefore more satisfactory to allow the fluid to be absorbed by rest and immobilization.

Lesions other than those of the menisci are much more indefinite, as articular cartilage shows up rather indistinctly and non-osseous loose bodies, unless of considerable size, are not usually seen. Only four lesions of this type, unassociated with lesions of the menisci, were seen in this series.

There have been no severe reactions following the injection of air into the knee joint; although, in about one quarter of the knees investigated, some effusion was produced. This did not persist for more than a few days and did not give rise to subsequent symptoms. In all cases in which the erythrocyte sedimentation rate was determined, it was normal. The effusion was probably the result of a mild irritative effect of the air. The air is usually completely absorbed in from four to seven days.

CONCLUSIONS

1. In the large majority of injuries of the menisci, the diagnosis can be made on clinical grounds alone. Air arthrography is, however, useful as an aid to diagnosis, particularly in mixed lesions, such as tears of the anterior cruciate ligament associated with tears of the menisci, or simultaneous lesions of both menisci. The diagnosis of lesions of the medial meniscus is simpler than the diagnosis of lesions of the lateral meniscus.
2. Arthrography is of less value in the diagnosis of other lesions of the knee joint, but is occasionally useful.
3. Arthrography affords interesting information regarding the movements of the menisci during flexion and extension of the knee. These movements can be studied both with roentgenograms and by fluoroscope. When the knee is flexed, the medial meniscus tends to be drawn backward out of the joint, and for this reason is not trapped.
4. Although the injection of air into a joint may produce a transient effusion, this is in no way harmful. Arthrography is a safe and simple procedure, when done with full aseptic precautions.

NOTE: The author is indebted to Air Commodore H. Osmond Clarke and to Wing Commander A. A. Butler for their advice and criticism.

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DISEASES AND DEFECTS OF THE MUSCULOSKELETAL SYSTEM IN AIR-CREW TRAINEES

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The following study is based on a survey of diseases and defects of the musculoskeletal system observed in 344,134 men who were examined for air-crew training (as bombardier, navigator, or pilot) at Army Air Forces Classification Centers and Army Air Forces Basic Training Centers. The group upon which these examinations were done was not a cross section of the average population. It was a selected population in the following respects: The ages ranged from seventeen to twenty-seven years; the men examined were presumably healthy; and they had been screened by at least one previous physical examination. The men were very anxious to pass the examination, and this caused them to conceal defects and deny symptoms.

TABLE I

Diseases and Defects of the Foot

Congenital defects	6
Arthritis	
Specific	2
Non-specific	5
Traumatic	1
Other types	3
Osteomyelitis	
Specific	1
Non-specific	4
Osteochondritis	1
Ankylosis	
Postinfectious	1
Posttraumatic	2
Posttraumatic deformity	5
Amputation of portion of foot	8
Fracture	
Malunion	1
Non-union	6
Paralysis of muscles	2
Hallux valgus	8
Hallux varus	1
Hammer toes	13
Pes planus	
Second degree, non-symptomatic	3
Second degree, symptomatic	191
Third degree, non-symptomatic	43
Third degree, symptomatic	181
Rigid type	4
Pes cavus	34
Other diseases or defects	26
Total	552

METHOD OF EXAMINATION

The physical examination carried out on this population was that prescribed by Army regulations for flying personnel. This examination is intended to be highly standardized and rigorous, but, under conditions of mass selection, it necessarily varies in uniformity and quality.

The examination of the musculoskeletal system was done with the examinees stripped.

TABLE II

DISEASES AND DEFECTS OF THE JOINTS AND SYNOVIAL MEMBRANES

General	
Congenital defects	8
Arthritis	
Acute infectious, non-gonorrheal	12
Acute infectious, gonorrheal	4
Rheumatoid	8
Atrophic	11
Hypertrophic	24
Posttraumatic	31
Osteo-arthritis	5
Osteochondritis	15
Ankylosis	
Postinfectious	5
Posttraumatic	19
Posttraumatic deformity	7
Calcification of joint capsule	4
Limitation of motion due to disease and defects of soft parts, alone or in combination	46
Luxation	2
Subluxation	11
Recurrent sprains	35
Other diseases or defects	43
Shoulder	
Recurrent dislocation	24
Hip	
Legg-Perthes disease	8
Coxa vara	3
Coxa valga	1
Slipped epiphysis	1
Posttraumatic deformity of joint	5
Knee	
Legg-Perthes disease	2
Fractures and dislocations of semilunar cartilage	68
Recurrent dislocation of semilunar cartilage	27
Operation for fracture or dislocation of semilunar cartilage	7
Laceration of cruciate ligaments	9
Genu varum	1
Relaxation of ligaments and joint capsule	24
Recurrent dislocation of patella	2
Fracture of patella with non-union	2
Total	474

A group of examinees, the size of which depended upon the area of the examining room and the number of medical examiners available, stood facing the examiners in staggered lines so as to allow full inspection of each individual. Scars, deformities, and abnormalities of the musculoskeletal system were recorded. The examinees then performed a series of exercises, designed to disclose abnormalities of function. Under ideal conditions, this close search for deformities and the tests for range of motion of joints, muscle coordination, strength, and agility should have made manifest all but a minimum number of structural defects, weaknesses, and musculoskeletal abnormalities. In practice, this ideal standard could not be reached when it was necessary to examine large groups.

Among the 344,134 examinees, a total of 1,856 (5.39 per 1,000) disqualifying defects were found in 1,561 men (4.53 per 1,000). The results of the examinations are shown in Tables I to VIII, inclusive.

ANALYSIS OF FINDINGS

Chart I shows the relative frequency of defects, according to the categories in Tables I to VIII.

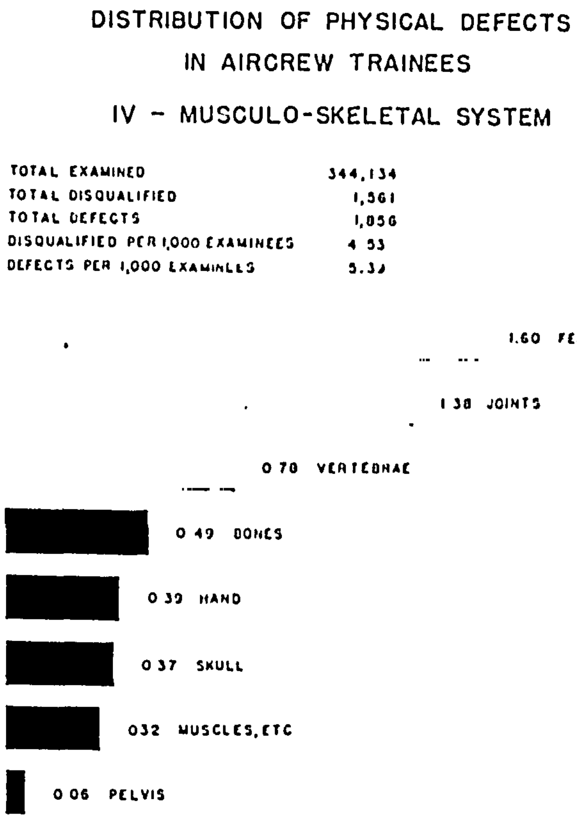

CHART I

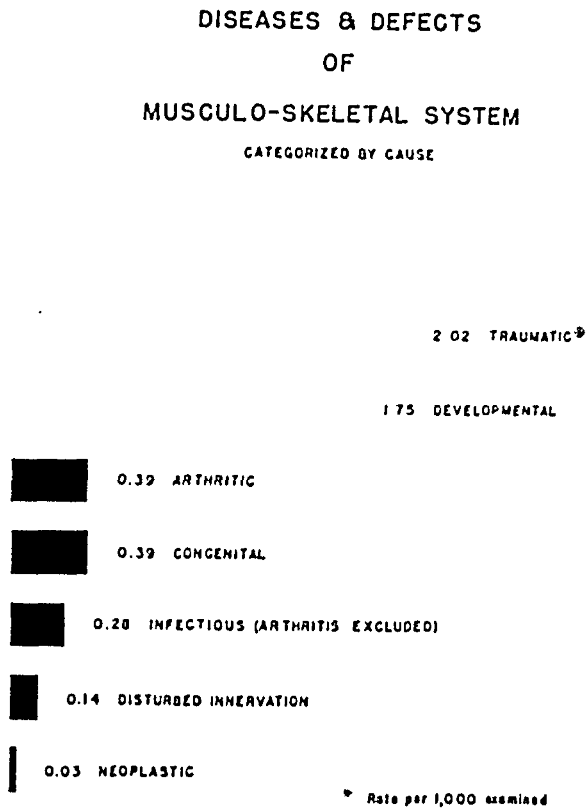

CHART II

TABLE III

Diseases and Defects of the Vertebrae

Congenital	
Spina bifida	
Occulta	19
Vera	4
Spondylolisthesis	31
Spondylosis	3
Hemivertebra	7
Sacralization of lumbar vertebra	9
Other congenital defects	11
Infectious	
Osteomyelitis, non-tuberculous	2
Osteitis	2
Spondylosis	2
Osteochondritis	3
Other infections	4
Traumatic	
History of fracture	87
Fracture-dislocation	2
Dislocation	8
Posttraumatic deformity	10
Other defects	16
Cause Undetermined	
Scoliosis	21
Kyphosis	11
Herniation of nucleus pulposus	12
Hypertrophy of ligamentum flavum	1
Symptomatic lordosis	2
Total	267

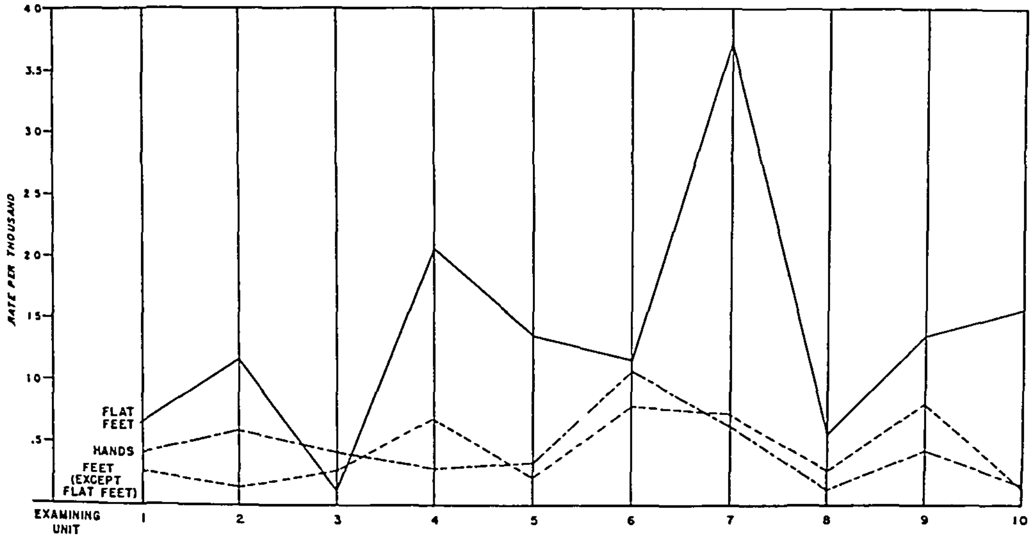

CHART III

TABLE IV

DISEASES AND DEFECTS OF THE BONES OF THE EXTREMITIES

Congenital deformities	11
Osteitis	2
Periostitis	1
Osteomyelitis	
Non-tuberculous	46
Tuberculous	1
Osteochondritis	2
Fracture	
Malunion	25
Non-union	30
Internal fixation	1
Synostosis	3
New growth	10
Other diseases or defects	35
Total	167

Chart II shows the relative frequency of these defects and diseases, according to the following categories:

1. Defects due to injury.
2. Defects of structural development.
3. The arthritides.
4. Congenital defects.
5. Defects due to infection.*
6. Defects of innervation.
7. New growths.

RESULTS

The interpretation of the physical findings was subject to differences in clinical judgment and in the application of pertinent regulations. These factors resulted in variations of the disqualification rates for various conditions by different examining units. Such ill-defined conditions as flat-foot were subject to the greatest range of variation..

Chart III illustrates the variation in disqualifications by different examining units

* Only one case of tuberculosis of the skeletal system was reported.

TABLE V

DISEASES AND DEFECTS OF THE HAND

Congenital defects	5
Arthritis	
Non-specific	2
Atrophic	2
Other types	1
Osteochondritis	3
Ankylosis	
Postinfectious	3
Posttraumatic	12
Deformities	
Postinfectious	5
Posttraumatic	20
Amputation of portions of hand	69
Fractures	
Malunion	2
Non-union	1
Paralysis of muscles	3
Other diseases or defects	7
Total	135

TABLE VI

DISEASES AND DEFECTS OF THE SKULL

Congenital defects of bones of vault	1
History of fracture	114
History of craniotomy	4
Traumatic defects	8
Other diseases and defects of vault	1
Other diseases and defects of bones and face	1
Total	129

TABLE VII

DISEASES AND DEFECTS OF THE MUSCLES, TENDONS, FASCIAE, AND BURSAE

Muscles	
Congenital defects	17
Myositis	14
Posttraumatic deformity	4
Paralysis	6
Atrophy	38
Other diseases or defects	16
Tendons and Fasciae	
Congenital defects of tendons	1
Laceration of tendon	2
Tenosynovitis	2
Other diseases or defects of tendons	4
Diseases or defects of fascia	2
Bursae	
Chronic bursitis	5
Total	111

for defects of the hands and feet. The ten examining units examined different numbers of men, ranging from 13,500 to 50,000. The numbers of examinees were large enough to exclude factors of chance. The rates of disqualification for flat-foot varied from 0.11 to 3.74 per 1,000 in different examining units. The disqualification rates for other defects of he foot and for defects of the hand showed no such wide variation.

TABLE VIII

DISEASES AND DEFECTS OF THE PELVIS

Osteomyelitis	1
Fracture	
Non-union	3
Malunion	2
Other diseases or defects	13
Total	19

TABLE IX

CONDITIONS REGARDED AS "CAUSES" OF BACKACHE

Spina bifida	
Occulta	19
Vera	4
Spondylolisthesis	31
Spondylosis	3
Hemivertebra	7
Sacralization of lumbar vertebra	9
Osteitis of vertebra	2
Spondylosis	2
Osteochondritis of vertebra	3
Fracture of vertebra	87
Fracture-dislocation of vertebra	2
Dislocation of vertebra	8
Posttraumatic deformity of vertebra	10
Scoliosis	21
Kyphosis	11
Total	219

TABLE X

	White Selectees (*Per 1,000*)	Air-Crew Applicants (*Per 1,000*)
Rejections for musculoskeletal defects*	22.6	3.41
Rejections for flat-foot	4.9	1.23
Rejections for other foot defects	1.4	0.38

* Excluding defects of the feet for both groups, and a history of skull fracture in the case of air-crew applicants.

These findings suggest that, among medical officers, there is common agreement neither as to what constitutes flat-foot, nor as to the degree of flat-foot which should be considered disqualifying. The term "flat-foot" will remain unsound semantically until meticulous definitions of each degree of flat-foot are generally agreed upon. In the present state of confusion, it might be better to discontinue the use of this phrase and to substitute such terms as "foot strain", "torsion of the talus", "relaxed plantar ligaments", "pronation of the foot", and "structural weakness of the foot". These terms at least suggest an attempt at diagnosis, and they can be given more meaning by grading the conditions as mild, moderate, or severe. Such diagnoses are open to criticism, but they are an improvement on the term flat-foot, which merely describes certain anatomical variations, as interpreted by varying schools of orthopaedic thought.

Table IX shows the number of cases of various conditions sometimes considered to be "causes" of backache. When roentgenograms reveal such defects as those listed in Table IX, it has become customary to regard the findings as confirmatory evidence of the

organic causes of backache. These air-crew applicants may be presumed to have been free of backache, or at least to have been confident that they could "get by" during their training; yet they showed a moderate number of the "causes" of backache. Since the skeletal system was not examined by roentgenogram routinely, but only when there was special indication, it is certain that the "causes" of backache are far more common than were reported for these examinees. There is strong evidence to suggest that frequently these defects exist without causing symptoms, and that their presence is not conclusive proof that a complaint of backache has an organic basis.

It does not necessarily follow that, because an individual with a backache is found to have an abnormality of the vertebral column, which existed before his symptoms developed, his backache is caused by the abnormality. Despite the presence of such roentgenographic findings, the backache may be due to other causes, such as prostatitis or psychoneurosis.

A detailed comparison between the disqualifications per 1,000 among air-crew applicants and the rejections of white Selective Service registrants, as reported by Rowntree, McGill, and Edwards [1], is not possible, due to differences in the methods of recording the defects. The comparisons in Table X, however, indicate that the air-crew applicants were a highly selected group.

The relatively low rate of disqualification for musculoskeletal defects justifies the policy of screening applicants for physical defects before they are sent to air-crew examining centers.

1. Rowntree, L. G.; McGill, K. H.; and Edwards, T. I.: Causes of Rejection and the Incidence of Defects Among 18 and 19 Year Old Selective Service Registrants. J. Am. Med. Assn., **123**: 181–185, 1943.

ACUTE INSTABILITY OF THE LIGAMENTS OF THE KNEE AS A RESULT OF INJURIES TO PARACHUTISTS

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Modern military training has greatly increased the incidence of traumatic instability of the knee. This has been especially evident at Fort Benning, a Post devoted to advanced infantry training, where the violent combat exercises and obstacle courses in Officer Candidate School, as well as the hazards peculiar to parachute jumping, make injuries of the ligaments of the knee a source of many hospital admissions. These injuries are serious, not only from the point of view of the prolonged initial disability, but also because of the high incidence of late symptoms. Too frequently, these patients complain of persistent pain, weakness, and instability in their knees and show an increased susceptibility to joint effusions after subsequent trivial injuries. The present study was undertaken with the aim of minimizing these residual symptoms.

The literature on injuries to the ligaments of the knee is remarkable for the contradictions and divergent statements on all phases of the subject. Even the surgical anatomy is variably interpreted, as described by Brantigan and Voshell in 1941. Within the past five years, however, a number of outstanding investigations [1,3,4,8] have crystallized certain facts from the mass of diversified opinions, and there is now general agreement on at least the following points:

1. The knee is a complicated weight-bearing joint with a combined hinge, gliding, and rotary action.
2. The joint is supported by active muscle power, as well as by the ligaments.
3. The ligaments also serve to direct the muscle power.
4. The ligaments are mutually reinforcing and function as a team, so that the loss of a single ligament does not produce a major instability.
5. Solitary ligaments are rarely injured.
6. The knee should be considered as a functional unit.

This concept of the knee as a functional unit (the "physiologic joint" of Palmer) is fundamental. Much of the confusion in the literature can be traced to neglect of this principle and to preoccupation with the individual ligaments or elaborate surgical reconstructions, with insufficient emphasis on the ultimate functional recovery of the knee as a whole.

The purpose of this paper is twofold: first, to describe a new mechanism of injury causing instability of the ligaments of the knee; and, second, to report the results of conservative treatment in a large series of cases.

CLINICAL MATERIAL

This series comprises eighty-five cases of acute instability of the ligaments of the knee treated at this Post during the past three years. In every case, abnormal mobility was demonstrated clinically; if any doubt existed, or if the initial examination did not specifically describe instability of the joint, the case was excluded from consideration. Also excluded were such acute derangements of the knee as "sprains" and effusions without instability, dislocated patellae, ordinary meniscal tears, and unstable knees due to depressed fractures of the tibial plateau. Late cases of instability were similarly excluded, although a few of them were followed in order to observe the effects of intensive quadriceps exercises, and to study the incidence of degenerative changes in the joint. No attempt was made to use these cases as controls.

In Table I the cases are arranged according to the cause of injury, the severity of

TABLE I

ETIOLOGY, TYPE, AND SEVERITY OF INSTABILITY OF LIGAMENTS OF THE KNEE

Mechanism of Injury	Number of Cases	Side		Predominant Instability			Severity			
		Right	Left	Abduction	Adduction	Other	Mild	Moderate	Severe	Undetermined
Parachute injuries:										
Opening shock	59	10	49	59	0	0	5	8	30	16
Landing impact	8	1	7	5	2	1	2	2	2	2
Obstacle courses	9	2	7	8	1	0	1	4	0	4
Sports	5	3	2	5	0	0	2	1	0	2
Miscellaneous	4	2	2	3	0	1	1	0	0	3
Totals	85	18	67	80	3	2	11	15	32	27

injury, and the type of instability. Since the ligaments are mutually reinforcing, it is impossible to determine from clinical examination of a given knee exactly which ligament or set of ligaments has been injured; the pattern of instability has therefore been described in terms of the direction of abnormal mobility. The overwhelming majority are abduction injuries, but few of them show a pure, unmixed instability. The usual clinical picture is a diffuse instability in more than one axis, and the most common clinical pattern is a "severe-abduction-plus-moderate-anterior" instability, involving the left knee five times as frequently as the right knee. Other types were rare; one complete anterior dislocation and three adduction injuries were observed.

The severity of injury is tabulated by measuring the degrees of angular widening of the joint space, as compared with the patient's opposite knee (Figs. 5-A and 5-B). This is more satisfactory than West's method of recording the "spread" of the joint space in millimeters, since it takes into account the appreciable laxity of some perfectly normal knees and is less subject to roentgenographic distortion. To facilitate the measurements, an adjustable hinged frame was constructed, on which the thighs were strapped together; roentgenograms were made while the legs were abducted simultaneously.

The following standards are suggested for gauging lateral instability:

ANGULAR WIDENING OF THE JOINT SPACE

Position of Knee	Mild (*Degrees*)	Moderate (*Degrees*)	Severe (*Degrees*)
Full extension	0 to 2	3 to 5	Over 5
Semiflexion (15 degrees)	0 to 4	5 to 10	Over 10

The following standards are suggested for gauging anteroposterior instability:

TIBIAL SHIFT

Position of Knee	Mild (*Millimeters*)	Moderate (*Millimeters*)	Severe (*Millimeters*)
Flexed to 90 degrees	0 to 4	5 to 10	Over 10

These numerical values for "mild", "moderate", and "severe" were established arbitrarily. Although some investigators may feel that they are too high or too low for a particular situation, they at least fill the need for a concise and objective basis for clinical examination. Throughout this study, every effort was made to secure uniformity of obser-

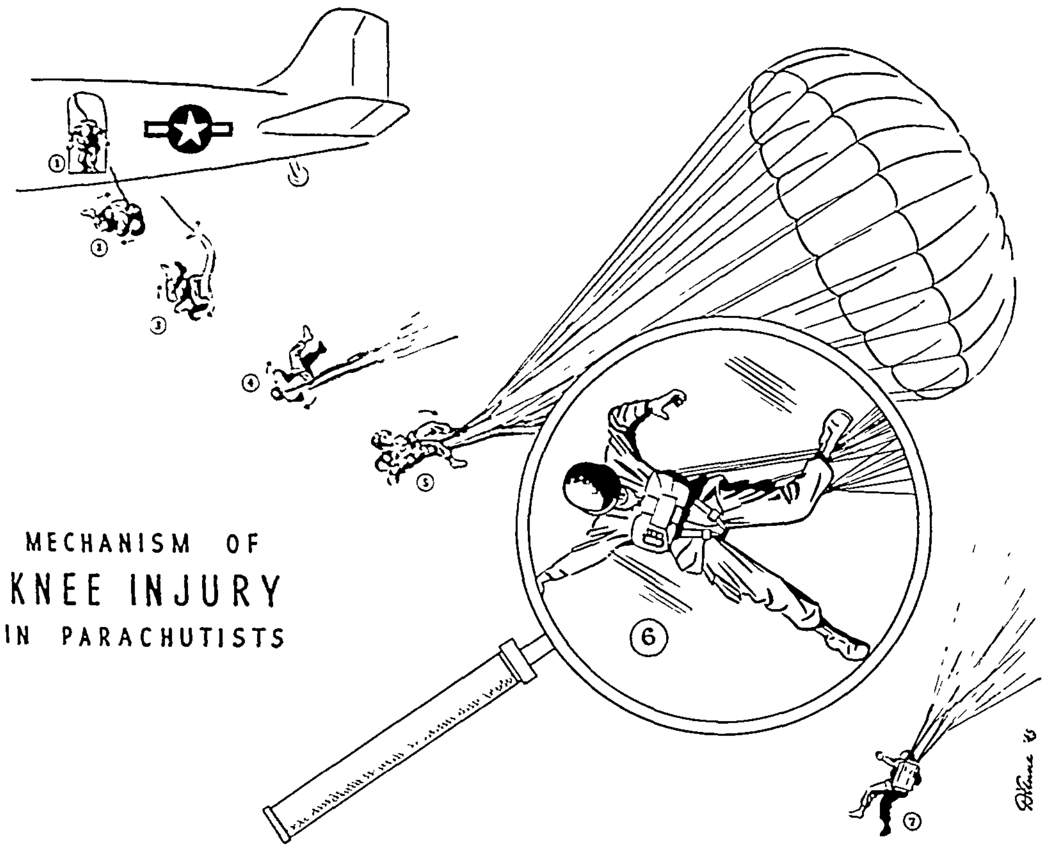

FIG. 1

Diagrammatic sequence of events in the "opening-shock" parachute injury. At phase No. 6, the left lower extremity is abducted by the taut suspension lines, which tear the tibial collateral ligament. The opening shock is a force of considerable violence, occasionally causing fractures of the shaft of the femur or separation of the symphysis pubis.

vations by systematizing the method of examination and adhering to objective standards. Consistency in reporting results was further assured by the fact that the authors personally treated 80 per cent. of the patients and followed their progress at monthly intervals, as long as they remained at Fort Benning.

MECHANISM OF INJURY

The majority of the patients were student parachutists who injured the left knee in the "opening-shock" phase of the parachute jump. Although this unique mechanism of injury concerns primarily the military surgeon, so many cases have accumulated that the sequence of events should also be of general orthopaedic interest.

Instead of leaving the plane in the approved feet-first, feet-together position, the parachutist dives out headfirst and is carried by his own momentum into a left-oblique somersault. As he tumbles forward, his left leg becomes entangled in the slack suspension lines of his parachute (Fig. 1); and then, when the canopy snaps open in mid-air, the left knee is wrenched violently upward and sideways.* The pain is excruciating; the jumper feels as if his knee were dislocated. He usually manages to land with his weight on the uninjured limb, without much additional pain; and then he either limps away or is picked up by medical corpsmen and transported to the hospital.

* The C-47 airplane has a single exit on the port side. This is undoubtedly the reason for the preponderance of injuries to the left knee in the opening shock. The definite lateralization to the left knee following injuries produced by other mechanisms is not explained so readily.

This composite history has been substantiated by experienced instructors at The Parachute School [11], and is further confirmed by the presence of brush burns on the leather along the medial aspect of the jumper's left boot, indicating where the suspension lines scraped across and applied the abducting force (Fig. 2).

The actual parachute landing corresponds to a free fall of about fifteen feet; but, due to uneven terrain, wind drift, and parachute oscillation, the nature of the impact is highly unpredictable. Most parachute injuries occur upon landing [7,13]; but, strangely enough, severe tears of the ligaments of the knee are relatively rare at this time, and they do not conform to such a uniform clinical pattern as opening-shock injuries.

Very few of the injuries in this series were produced by the more conventional mechanisms. Six per cent. were due to football and other sports, and 10 per cent. were incurred on obstacle courses, generally as the result of jumping from a height. These injuries tended to be relatively minor.

EXAMINATION AND DIAGNOSIS

As stated earlier, the pathognomonic feature of these injuries is abnormal mobility of the knee. In most cases, however, the instability was evidently overlooked during the initial examination, and the patient was usually admitted to the hospital with the diagnosis of internal derangement of the knee or traumatic synovitis, with no hint of the serious ligamentous damage. This failure to recognize the true nature of the lesion is understandable, since frequently the knee may be too painful to permit deliberate testing for instability, or the instability may be masked by effusion or muscle spasm. It is true, nevertheless, that a properly performed clinical examination will reveal the diagnosis. Several characteristic features distinguish the lesion: The patient walks guardedly, if at all; he observes his footing carefully and, when moving to the examining table, he cradles his injured limb over the good one. He gives a history of severe, direct violence, in contrast to the relatively trivial injuries which cause meniscal lesions. Typically, he complains that the knee "buckles inward" when he missteps. The knee shows soft-tissue swelling, tenderness, and frequently ecchymosis over the tibial collateral ligament, generally maximum at its femoral insertion. Full extension is prevented by pain and spasm, rather than by organic block, as is the case with dislocated menisci. The amount of intra-articular fluid is variable; in the more severe injuries less fluid accumulates, since it drains through the capsular tear and escapes into the soft tissues. In recent, severe injuries, the torn structure is often palpable as a loose, tender, subcutaneous mass along the course of the tibial collateral ligament.

Fig. 2

Actual brush burns on the parachutist's left boot. Compared with Fig. 1. (*Photo by U. S. Army Signal Corps.*)

Since the demonstration of abnormal mobility determines not only the diagnosis, but also the treatment and prognosis, the technique of examination merits special consideration. The ligaments are not considered individually, but stability is evaluated in terms of functional loss. Figure 3 illustrates the method of determining abduction instability, which is the type most frequently encountered. This is measured first in semiflexion—the position of effort—and then with the knee extended to the normal standing position. Adduction instability is estimated similarly. The knee is then tested for genu recurvatum, and

it is finally relaxed in 90 degrees of flexion to measure anteroposterior instability.

If the knee is too painful to permit adequate relaxation, some form of anaesthesia is recommended by Böhler, by Palmer, and by West. The authors prefer a low spinal anaesthesia, consisting of fifty milligrams of novocaine; this abolishes pain and reflex muscle spasm, yet preserves enough voluntary muscle power to facilitate the application of a cast. With the patient thus relaxed, examination can be deliberate and unhurried. The knee is tested for all types of instability; it is flexed through a full range of motion to rule out organic block; and, if necessary, fluid is aspirated.

FIG. 3

A convenient position for eliciting abduction instability. Relaxation of the thigh muscles is essential for an adequate examination.

TREATMENT

The present treatment is based on Böhler's dictum that the ligaments of the knee, in common with ligamentous structures elsewhere, unite satisfactorily if they are immobilized long enough in the proper position. Accordingly, the patients are immobilized in plaster casts from toes to groin; the knee is maintained in varus position (or other corrective position, depending upon the type of instability) and in about 30 degrees of semiflexion. This relieves the major tension from the capsule and from the cruciate and collateral ligaments, and is the most comfortable position for an injured knee. It is expedient to apply the cast in two sections; the lower half is allowed to harden before the knee and thigh are incorporated. In this way, the unstable knee is easier to control, and accurate alignment of the joint is assured.

The duration of immobilization varies according to the severity of the injury. After three or four weeks, the knee is stable enough in general to permit weight-bearing; and the initial cast is replaced by a snug walking cylinder, which holds the knee in 5 degrees of flexion. The patient wears this cylinder for another three to five weeks; immobilization is usually discontinued at the end of from six to ten weeks.

From the very beginning of treatment, a continuous program of exercises is maintained in order to preserve the tone and substance of the thigh musculature. Some quadriceps atrophy inevitably occurs while the cast is in position, and the average limb shrinks one and one-half inches in circumference, as compared with the opposite thigh; but, as soon as the cast has been removed, exercises are intensified to make good this loss. Each patient is required to devote an hour a day to supervised quadriceps exercises, starting with simple flexion and extension of the knee in bed, and progressing through knee bends, leg raising, chair climbing, weight lifting, running, and cross-country bicycle rides, to the limit of his power and endurance. Pain alone is not regarded as a contra-indication; in fact, the only valid reason for suspending, or even decreasing, the quadriceps exercises is the presence of soft-tissue induration or of chronic joint fluid, which increases after a provocative test. Barring such a complication, however, exercises are pursued as energetically as possible. The more effort the patient expends, the more rapid is his recovery (Chart I)[9,12,14].

In connection with the problem of support for the knee after the cast has been removed, a wide variety of appliances—from adhesive strapping to steel knee cages—have been advocated; in the patients described here, however, no supports were used other than a Thomas heel with a quarter-inch medial wedge. Hinged casts and braces are not physio-

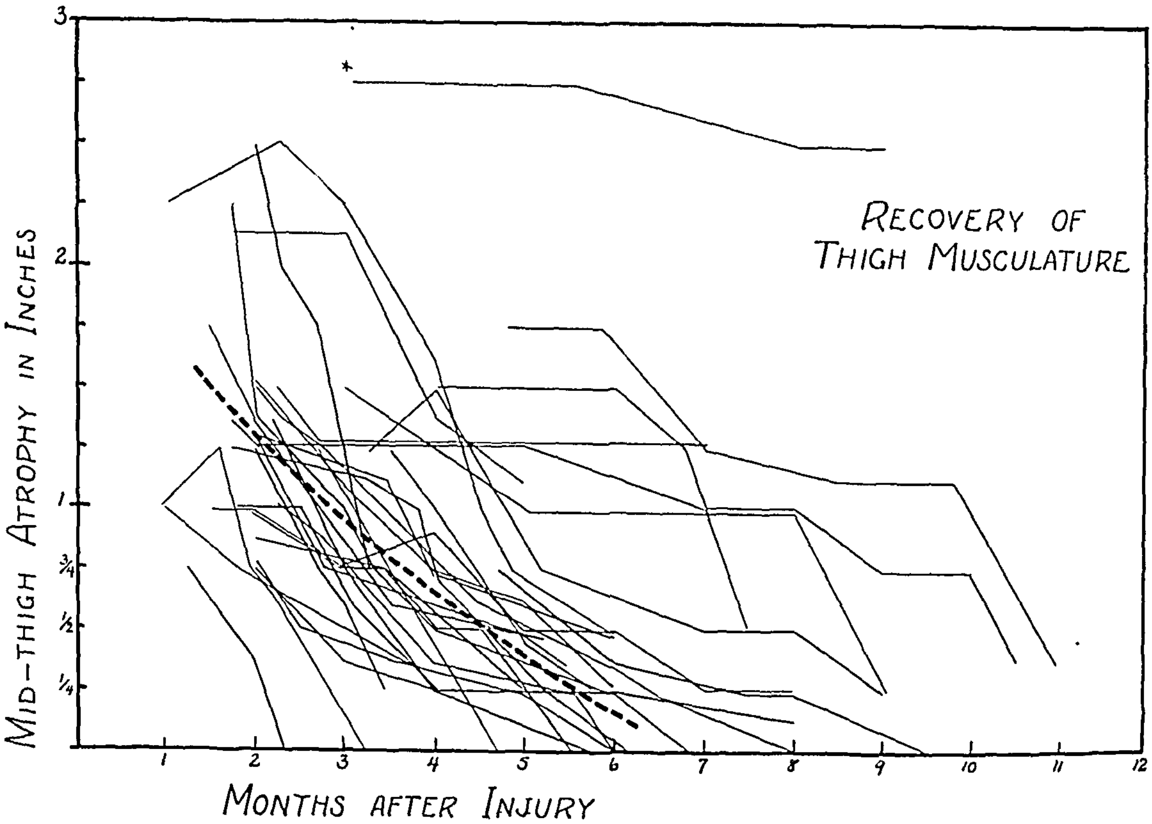

CHART I

Composite graph of the rate of quadriceps recovery in thirty-two cases. There is a remarkably close relationship between the recovery of the thigh musculature and the functional capacity of the knee.

* Case complicated by a diffuse unilateral muscle atrophy, presumably secondary to old poliomyelitis.

logical; no mechanical hinge can support the knee during its complex motions. Bandages and adhesive strapping merely limit the range of motion and promote further muscle atrophy; this in itself is sufficient to condemn them, apart from the fact that they furnish no real support for a weight-bearing joint. The heel wedge, on the other hand, is comfortable; it takes excess strain off the tibial collateral ligament; and it does not induce the patient to favor the limb. Further protection for the injured ligaments is assured by assigning the patient to limited military duty for at least six months from the date of injury, or until healing is considered complete.

ANALYSIS OF RESULTS

In order to secure an objective analysis of end results, and to avoid such vague classifications as "good", "fair", and "poor", the authors have worked out a system of evaluating the functional capacity of the knee in terms of twelve specific clinical criteria. These criteria are listed in Table II and are explained briefly as follows:

1. *Pain:* The patient is questioned regarding such symptoms as pain on twisting movements, aching at night after prolonged exercises, and pain in inclement weather. Individual pain tolerance is necessarily a factor here.

2. *Endurance:* This can be estimated objectively on the basis of measured performance. The standards are high; endurance is not considered normal in a young person unless he can walk twelve or fifteen miles.

3. *Agility:* This is considered apart from endurance. Frequently one finds patients who can work all day long, while standing, but can no longer run or engage in sports.

4. *Quadriceps Atrophy:* This mid-thigh measurement actually includes all the thigh muscles, but clinically the quadriceps manifests more atrophy than the others. It is meas-

ured as the difference in circumference between the two thighs; and it is an extremely significant finding, as will be explained later.

TABLE II

CLINICAL CRITERIA AND STANDARDS FOR EVALUATING THE FUNCTIONAL CAPACITY OF THE KNEE

Criterion	Quantitative Rating			
	1	2	3	4
Pain (P)	None	Slight	Moderate	Severe
Endurance (E)	Normal	Walk of 5 to 10 miles; slow trot of 1 mile	Walk of 3 to 5 miles; slow trot of ½ mile	Walk of less than 3 miles
Agility (A)	Normal	Cross-country running; short-stop sports; few symptoms	Cross-country walking; can run on level ground	Cannot run on level ground
Quadriceps atrophy (Q)	None	Up to ½ inch	¾ to 1¼ inches	1½ inches or more
Subjective instability (S)	None	Slight	Moderate	Severe
Sagittal instability (AP)	None	0 to 4 millimeters	5 to 10 millimeters	Over 10 millimeters
Abduction instability in semiflexion (FL)	None	0 to 4 degrees	5 to 10 degrees	Over 10 degrees
Abduction instability in extension (EX)	None	0 to 2 degrees	3 to 5 degrees	Over 5 degrees
Intra-articular fluid (F)	None	Slight and transient	Slight and chronic, or moderate and transient	Marked or persistent
Clicking (C)	None	Slight or intermittent clicking	Moderate and persistent	Painfully severe and constant
Range of motion (M)	Normal	Flexion to 140 degrees	Flexion to 120 degrees	Less than 90 degrees of flexion
Determination and attitude (D)	Normal	Less than optimum effort and perseverance	Discouraged and uncooperative	Markedly defective attitude; exaggerated disability

Instability is evaluated under four separate headings:

5. *Subjective Instability:* This is graded according to the patient's complaints of "slipping", "going out of place", or "buckling" of the knee, with due consideration for the causative activity.

6. *Sagittal Instability:* This is also called anteroposterior instability, or "drawer action".

7. *Abduction Instability in Semiflexion:* This is measured roentgenographically, with the limb forcibly abducted and the knee in 15 degrees of semiflexion. Too much flexion is to be avoided, since it introduces excessive torque on the femur.

8. *Abduction Instability with the Knee in Extension:* This is measured roentgenographically, with the knee in the normal standing position, not in hyperextension.

9. *Intra-Articular Fluid:* Both the amount of fluid and the frequency of recurrence are considered here.

10. *Clicking:* This term includes various cracking and snapping sounds. No true locking has been observed in this series of cases.

11. *Range of Motion:* This is measured in degrees of flexion, starting from 0 degrees at full extension.

12. *Determination and Attitude:* The patient's cooperation, perseverance, and determination to get well are highly important factors. In the Army, as with industrial compensation, the secondary gain derived from disability frequently influences and prolongs the ultimate recovery.

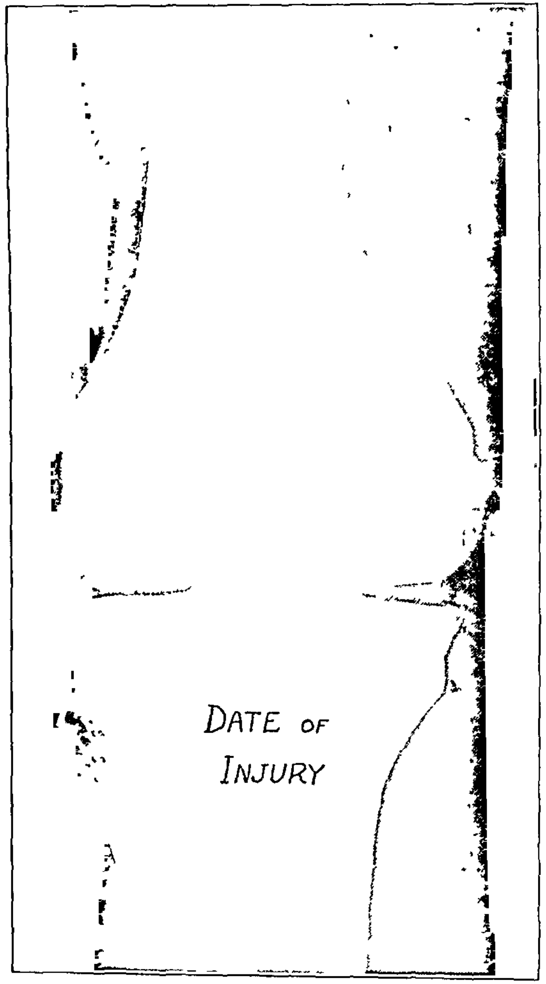

FIG. 4-A

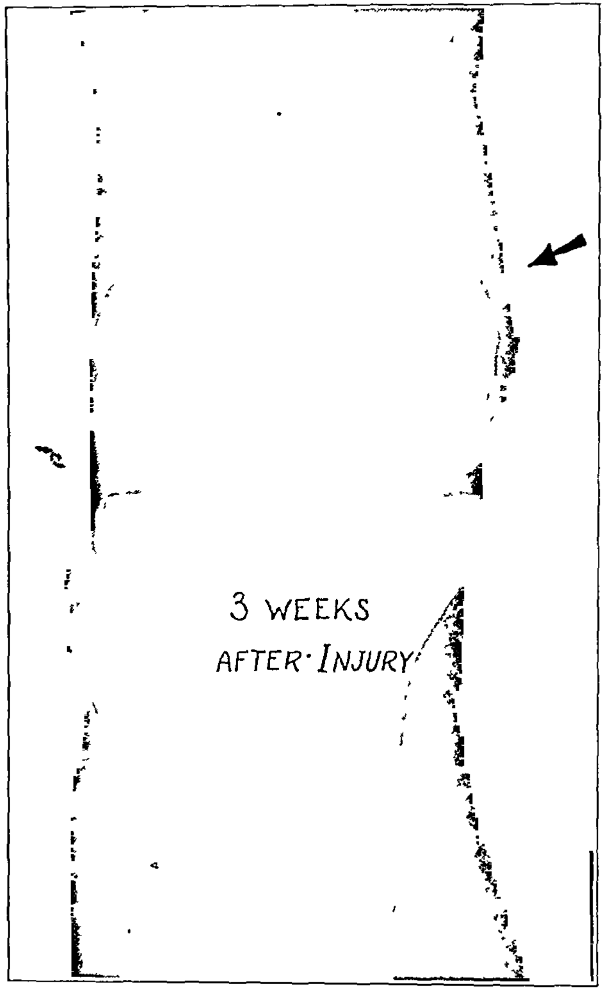

FIG. 4-B

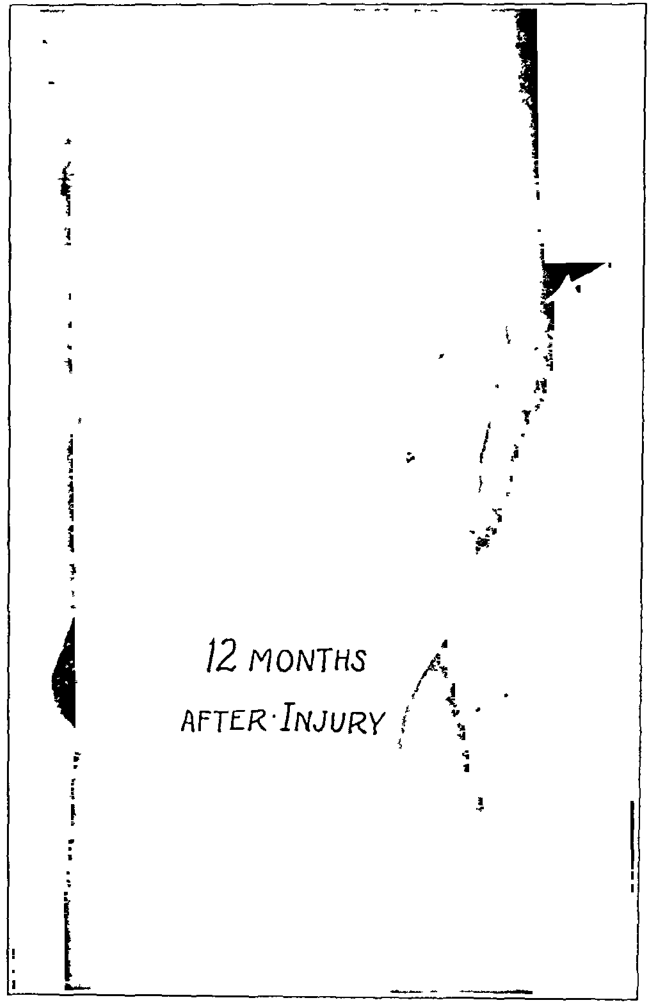

FIG. 4-C

Roentgenograms illustrate the development of a shadow typical of so-called Pellegrini-Stieda disease, following abduction injury. Clinically, this case presents a slight prominence at the site of calcification; occasionally this prominence becomes tender after repeated traumata, but otherwise no symptoms are produced. Stability of the knee is good; there is no limitation of motion. The patient is now an instructor at The Parachute School and is extremely active physically.

While other criteria might well be included in this list, we feel that those selected are representative enough to furnish an integrated picture of the functional recovery of the knee. By measuring the criteria objectively, in numerical units, according to rigid clinical standards, the inconsistencies arising from reliance upon personal judgment alone have been reduced to a minimum. Practical application of this method is illustrated in the case reports; in the authors' experience it has provided a convenient, sound basis for comparing end results.

In evaluating the over-all results of conservative treatment, the first consideration, naturally, is the recovery of stability of the knee. Healing of the ligaments in the abduction injuries has been very satisfactory. In the last sixty consecutive cases, including all degrees of injury, the final roentgenographic measurements demonstrate that fully 95 per cent. recovered with less than 5 degrees of residual instability*. Even the most extreme abduction injuries, with apparently complete rupture of the tibial collateral ligament, showed only 2 or 3 degrees of residual abduction instability (Cases 1 and 2). Moderate injuries healed with a final average of 2 degrees, and the mild cases showed even less than that. These minor degrees of instability are tolerated quite well, and do not interfere appreciably with the patient's endurance or agility. Only when the residual abduction instability exceeds 5 degrees do the symptoms become troublesome. Such patients, who comprise approximately 5 per cent. of this series, complain of weakness, recurrent effusions, and pain to such an extent that they are no longer fit for military service. As a clinical rule of thumb, therefore, it may be stated that abduction instability in excess of 5 degrees is unsatisfactory; less than this is perfectly compatible with a good functional result.

End results in other types of instability were also favorable, although the number of cases is too small to afford dependable statistics. Adduction instability has proved relatively less disabling than abduction lesions of equal degree, because of the closer anatomical supporting action of the tensor fasciae latae and the iliotibial band (Case 6). With regard to anterior and posterior instability, in the more pronounced cases (with more than one centimeter of drawer action) the patients often complain of slipping sensations; but symptoms are generally not troublesome unless abduction weakness is also present (Case 3). In summary, while the results of conservative treatment are overwhelmingly satisfactory in so far as stability is concerned, it must be kept in mind that stability alone does not wholly determine the functional result.

Of all the criteria listed, the most reliable single index of functional recovery is the amount of quadriceps atrophy. A sound, firm quadriceps is associated with a good knee; and, conversely, patients with shrunken thighs invariably complain of fatigability, diffuse pain in the knee, and buckling sensations,—the well-known "weak-knee syndrome" described by Palmer. The supporting role of the thigh muscles becomes doubly important when the ligaments are torn, as is shown by the studies of Brantigan and Voshell and of DeLorme; indeed, the functional recovery of these patients is in direct ratio to the quadriceps recovery. Clinical experience has shown that atrophy in excess of three-quarters of an inch is almost invariably accompanied by symptoms; and, when it approaches one and one-half inches, the patient displays so much disability that, even with excellent healing of the ligaments, he cannot be considered to have achieved a good result. This is the reason for insisting upon quadriceps exercises as an essential part of the treatment. Chart I illustrates graphically the actual rate of quadriceps recovery and, with remarkable accuracy, the parallel functional recovery of the knee as a whole. In this series, the average cooperative patient shows full quadriceps recovery in from five to seven months. In some cases a longer time is required, but if the patient shows more than one inch of atrophy at the end of six months, his recovery is considered to be delayed. As indicated in Chart I,

*Roentgenographic measurements of residual instability are not available in the earlier cases; however, the clinical estimates of instability in these cases tend to substantiate the figures given.

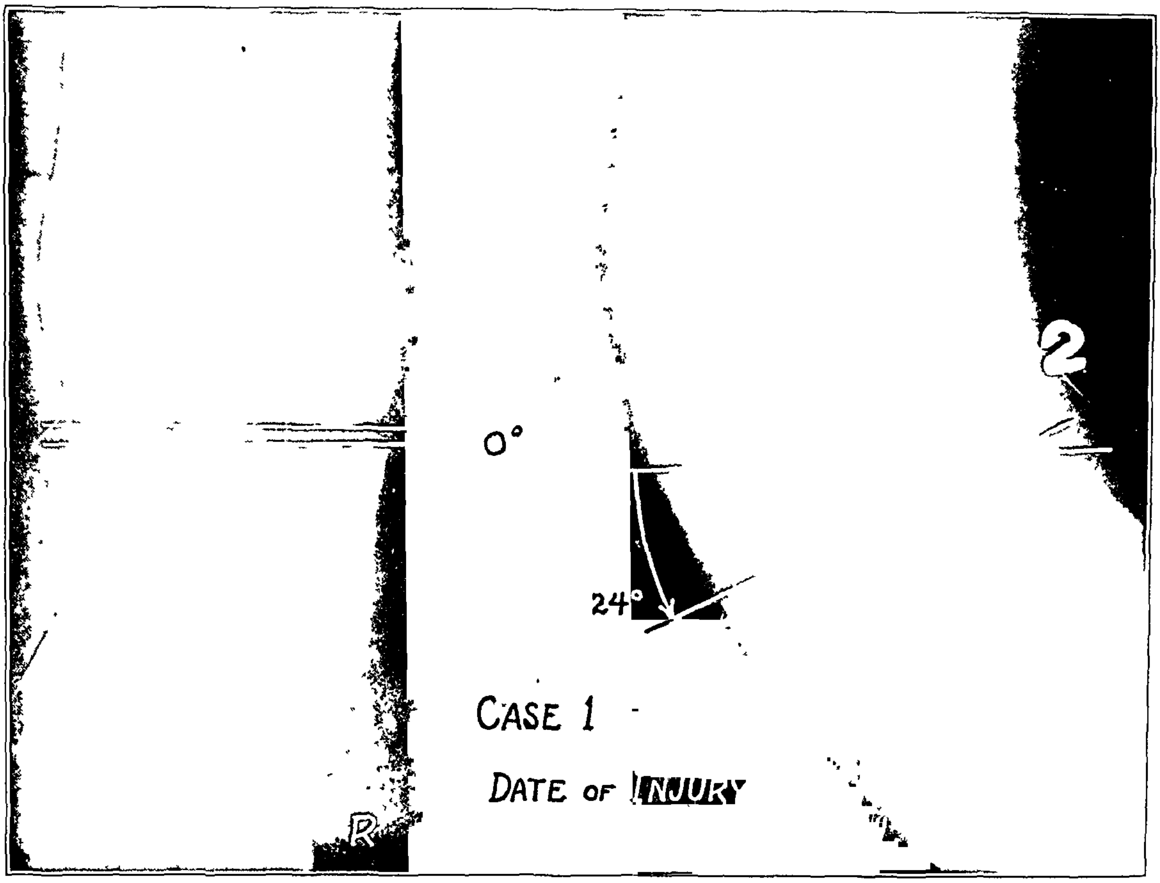

FIG. 5-A

Case 1. Roentgenograms demonstrate severe abduction instability of the left knee in semi-flexion. The right knee is normal.

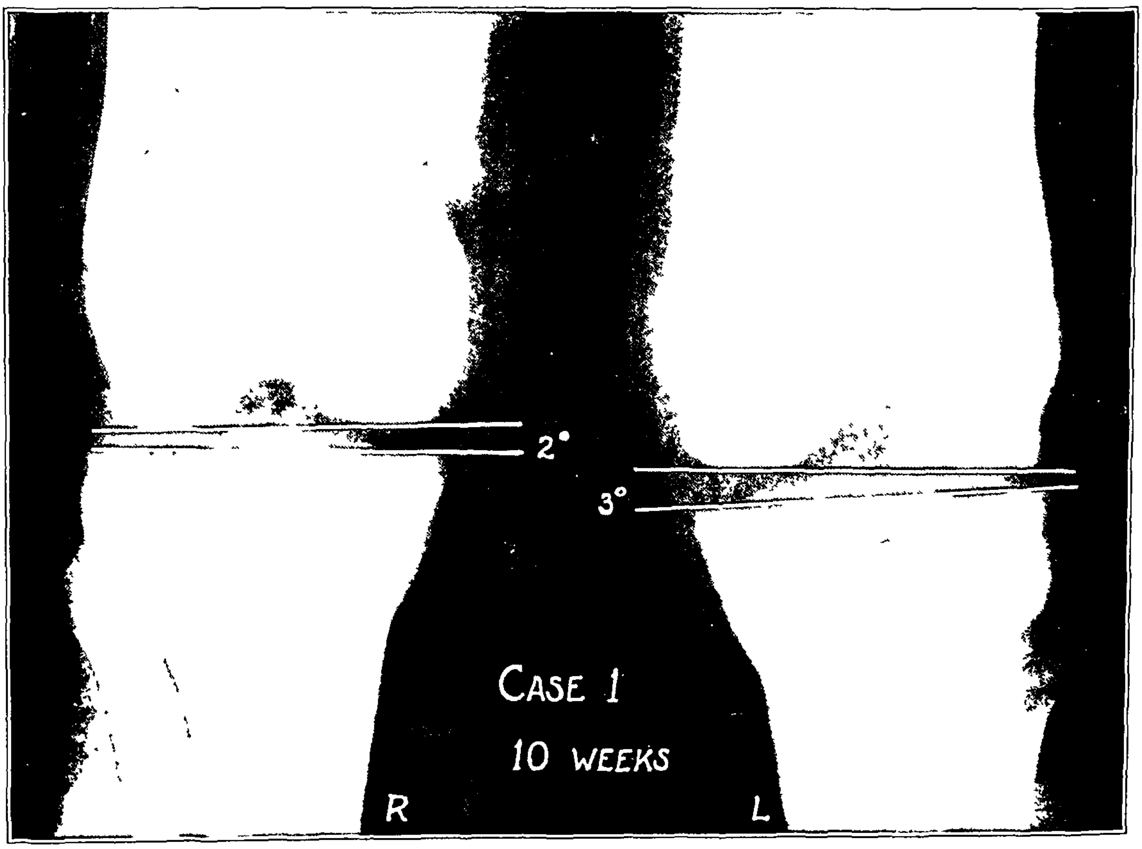

FIG. 5-B

Ten weeks after injury, very slight residual instability is seen.

six cases fall into this group: One did not improve because of a diffuse muscle hemiatrophy, presumably due to old poliomyelitis; two others were considered generally poor results (see Case 3); in the remaining three cases the atrophy was simply due to laziness and the patient's neglect of the prescribed quadriceps exercises. With proper coaching and more intensive exercises, the response of the quadriceps muscle in these three cases was reflected symptomatically in greater endurance, agility, and freedom from pain (see Case 5).

Intra-articular fluid is rarely a troublesome symptom, since it usually disappears within from four to six months and does not recur. In a small percentage of cases, however, the effusion is unusually persistent, and fluctuates with the amount of physical activity and subsequent trauma (Case 3). Usually, such cases are also unsatisfactory from the point of view of poor intrinsic stability, chronic thickening of the capsular structures, and excessive quadriceps atrophy. They are unduly susceptible to injury, and effusions develop after minor sprains. Careful rehabilitation of the thigh musculature will minimize the episodes of effusion and improve the functional capacity better than will any artificial brace or support.

Limitation of motion has been a negligible problem, because almost all of the patients recover complete extension and normal flexion within six months. Ultimately, every patient except the one with the dislocated knee (Case 7) obtained at least 135 degrees of flexion, which is sufficient for all ordinary pursuits.

A common roentgenographic feature of healing is the development of calcific shadows along the course of the tibial collateral ligament, the so-called Pellegrini-Stieda disease. This complication was present in fully 60 per cent. of our cases. Typically, it first appears in from three to six weeks as a flocculent shadow, which gradually condenses to a curvilinear residue, more or less closely associated with the femoral attachment of the tibial collateral ligament (Figs. 4-A, 4-B, and 4-C). These patients may show persistent tenderness at the site of calcification, and occasionally slight pain on full flexion; but, in the authors' experience, no actual disability has been attributable directly to the lesion, and it is of roentgenographic rather than of clinical importance [6,10].

In order to illustrate specifically the regimen of conservative treatment, the following cases are reported in some detail. They represent a variety of severe injuries of the ligaments, and include examples of both good and poor end results.

CASE REPORTS

Severe Abduction Injury with Good Result

CASE 1. A soldier caught his left boot in the suspension lines of his parachute and experienced violent, numbing pain in his knee during the opening shock. The limb buckled medially on attempted weight-bearing, and he was taken to the hospital with a diagnosis of traumatic synovitis. Examination revealed painful limitation of motion, and diffuse soft-tissue swelling and tenderness along the medial aspect of the left knee. Gross instability was evident, although the exact amount was obscured by muscle spasm. After a low spinal anaesthesia, however, the patient showed extreme instability of the left knee, particularly in semiflexion (Fig. 5-A), as well as slight anteroposterior hypermobility. He had a full range of active motion while under anaesthesia.

He was immobilized for six weeks in a toe-to-groin plaster cast, applied according to the technique previously described, with the knee flexed at 30 degrees and in slight varus correction. This cast was replaced by a walking cylinder, which was employed for four more weeks, and maintained the varus position. During this time, performance of the quadriceps exercises was rather perfunctory and, upon removing the cylinder cast, the patient had excessive atrophy of the thigh (two and one-half inches). The program of muscle rehabilitation was hampered at first by a persistent effusion, but this subsided after several aspirations and thereafter his progress was rapid.

Four months after the injury, stability was very good (Fig. 5-B). There was only 1 degree of residual abduction instability in semiflexion, none in full extension, and only slight anteroposterior hypermobility. The effusion was almost gone. Atrophy was one and three-quarters inches.

At the end of *five months*, there was considerable symptomatic and clinical improvement. The patient was able to walk five miles, but he still felt that the knee was weak when he stepped on uneven

ground. He had a full range of motion. There was very slight swelling; atrophy was three-quarters of an inch.

After *six months,* the knee was subjectively stronger and the patient was able to walk ten miles. He could trot for one mile over uneven ground, with minimum discomfort, and was able to ride a bicycle for long distances. Although the knee still was somewhat unstable when he participated in active sports, such as baseball and volleyball, his agility was improving rapidly. Objectively, the residual instability was minimum. No swelling was apparent, even after prolonged activity. The range of motion was completely normal. Atrophy was one-half inch. His attitude and perseverence were excellent, and he remarked that his knee was "getting stronger all the time".

Using the criteria and standards advocated in Table II, this patient's functional capacity at the end of six months can be condensed into the following formula:

P	E	A	Q	S	AP	FL	EX	F	C	M	D	Disability Rating *
2	2	2	2	2	2	2	1	1	1	1	1	1.5

Comment: In retrospect, the quadriceps exercises should have been more intensive while the patient was wearing his casts. The present exercise program devotes especial attention to patients in casts, so that such severe atrophy is no longer encountered. After the cast has been removed, exercises should be increased gradually, to avoid any reactive effusion or soft-tissue induration. This patient is considered to have made an excellent recovery from such a severe injury. The results in this case refute the widely held opinion that surgical repair is essential in marked separation of the knee joint. Observation of many other equally good results after conservative treatment naturally raises the question as to whether the cures following operative treatment are not properly attributable to the postoperative immobilization, rather than to the surgical repair itself.

CASE 2. As this parachutist jumped from the plane, the man in front of him momentarily "froze" in the doorway, causing the patient to trip and to tumble out headfirst, with poor body position. He became entangled in the suspension lines and wrenched his left knee during the opening shock. Examination disclosed a rupture of the tibial collateral ligament, which allowed 15 degrees of abduction of the knee without anaesthesia. The knee was extremely tender at the femoral insertion of the tibial collateral ligament, and weight-bearing was impossible. His left boot showed a definite brush burn, similar to that shown in Figure 2.

The sectional toe-to-groin cast was applied, which held the knee in semiflexion and in the varus position. The cast was replaced in two weeks by a walking cylinder, which was removed seven weeks after the injury.

At the end of *three months* there was mild residual instability, amounting to 3 degrees of abduction in semiflexion, and slight anterior hypermobility. The joint was quite stable in extension. The patient stated that his knee still was weak and tended to buckle. Atrophy amounted to one and one-quarter inches. About 15 degrees of limitation of flexion was observed. The patient cooperated well in performing the prescribed exercises.

Five months after injury the patient showed a very good symptomatic result and had no difficulty with his knee, except that it ached in rainy weather. He walked seven miles without any trouble, and sprinted 300 yards in forty-seven seconds. Objectively, the stability was unchanged. There was no quadriceps atrophy. The patient cooperated energetically in the prescribed exercises, and had been working as a physical instructor on the Reconditioning Service.

At the end of *seven months,* this soldier had no complaints whatever. He was able to march twelve miles in military formation without pain, ran as well as ever, played baseball, shoveled dirt without pain, and performed strenuous field duties at the Infantry School. Except for the slight residual instability previously noted, his knee and thigh were clinically normal. His disability rating was 1.2. The patient returned to full military duty at his own request.

Comment: This is one of the best functional results obtained in the entire series. It substantiates the fact that a minor degree of residual instability is not in itself disabling, or even productive of symptoms; and hence cannot be used as the sole criterion of recovery. The only rational basis for evaluating a knee is in terms of its functional capacity.

* The average of the individual quantitative ratings furnishes a useful disability rating of the knee as a whole.

Abduction Injury with Poor Result

CASE 3. This parachutist's left knee was abducted violently by the suspension lines during the opening shock, and again when he struck the ground. Despite severe pain in the knee, he limped about with a cane and was treated for five days at his organization with physiotherapy and sleeping tablets. He finally had to be hospitalized because of persistent pain, as well as an alarming ecchymosis of the knee and leg. On admission, the diagnosis was tear of the tibial collateral ligament of the left knee, with possible injury to the fibular collateral ligament. Roentgenograms were negative. No clinical details were recorded as to the degree or direction of the instability.

The following information was abstracted from his clinical record. The patient was immobilized in the toe-to-groin cast (one stage) for six weeks. After the cast had been removed, swelling and oedema quickly developed, and a walking cylinder was applied for an additional three weeks.

Recovery was slow and unsatisfactory. When he came under the observation of the authors (four months after injury), he showed a persistent effusion that fluctuated with the amount of physical activity, but never entirely disappeared. Analysis of the fluid was as follows.

Volume:	30 cubic centimeters	
Character:	Turbid yellow with fibrinous flecks	
Total protein:	330 milligrams per 100 cubic centimeters	
Blood-cell count:	White blood cells	288
	Polymorphonuclear neutrophils	10 per cent
	Lymphocytes	90 per cent

Bacteriological examination showed no organisms on smear or culture. The fluid re-accumulated promptly after aspiration. Flexion was limited to 120 degrees. Atrophy of the thigh was one and one-half inches. The patient complained of recurrent dull pain after exercise, and a definite sense of instability, even while walking. Objectively, he showed thirteen millimeters of sagittal instability and 4 degrees of residual abduction instability. With the knee in full recurvatum position, however, this instability was not evident. Both knees displayed 10 degrees of recurvatum laxity. The patient mentioned that, unless he locked his knee in hyperextension, it tended to "slip sideways" on walking, and he had to concentrate on his footing.

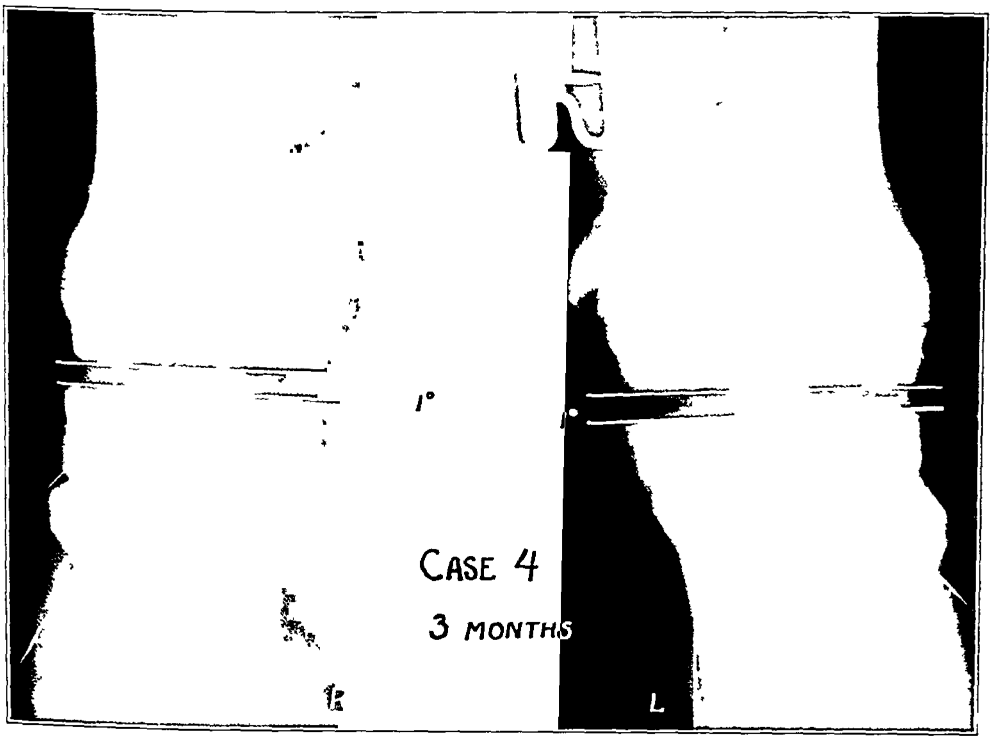

FIG. 6

Case 4. Very slight residual instability followed a severe abduction injury. Note the pronounced calcification of the tibial collateral ligament, still in the "evolutive" stage.

Five months after the original injury, the patient stepped into a rut, twisted his left knee again, and suffered a recurrence of pain and swelling that lasted for ten days.

At the end of *six months,* the knee still was weak and symptoms persisted. The patient could walk three miles and could trot short distances, but was unable to engage in active sports, such as tennis or volleyball, because sudden pivoting aggravated the swelling and caused the knee to ache all night. He also complained of painful clicking and of a tendency for the knee to buckle and slip, particularly on uneven ground. Objectively, the instability remained as described previously. Flexion was limited to 135 degrees. Atrophy of the thigh was one and one-quarter inches. The chronic effusion persisted. The patient cooperated poorly in the quadriceps exercises and frequently became depressed and irritable. His disability rating was 2.8.

Comment: The result in this case is probably the worst of the entire series, and illustrates several technical errors in diagnosis and treatment:

1. The serious nature of the injury was not appreciated at the initial examination, and consequently the patient was allowed to limp around for five days without immobilization. The authors have noted repeatedly that a delay of more than twenty-four hours in starting immobilization definitely prejudices the final result.

2. Immobilization was unsatisfactory. In such a serious injury, immobilization should have been continuous for ten weeks. Furthermore, it is technically awkward to support a painful, unstable knee in accurate alignment while applying the toe-to-groin cast in one stage. Sectional casts are strongly recommended.

3. Quadriceps exercises were not pursued systematically, largely because of lack of cooperation on the part of the patient. The resulting deterioration of the thigh muscles was an important factor in his poor endurance and agility.

4. A final factor contributing to poor stability was the amount of laxity of the normal knee. Patients who normally show appreciable genu recurvatum do not recover so well as those whose joint structures are congenitally more stable.

Severe Abduction Injury with Calcification of Tibial Collateral Ligament

CASE 4. This parachutist somersaulted forward upon leaving the plane, caught his left foot in the suspension lines, and wrenched his left knee during the opening shock. He was treated in his quarters for a day, with the diagnosis of acute traumatic effusion; but pain in his knee kept him awake all night and finally necessitated hospitalization. Examination on admission revealed generalized oedema about the knee and the medial aspect of the thigh and extreme instability of the tibial collateral ligament, which allowed at least 20 degrees of abduction without anaesthesia. "Surgical repair imperative" was the opinion of the admitting surgeon.

The patient was immobilized in the sectional toe-to-groin cast and later in a cylinder, which held the knee in varus correction for a total of six weeks. He was also fitted with a medial wedged heel. When the cast had been removed he showed good stability, but marked suprapatellar induration and stiffness of the knee were present.

Eleven weeks after injury the patient was very active physically; he played volleyball daily, although this exercise caused local warmth and transient swelling. There was still considerable suprapatellar induration, and return of motion was delayed. Range of flexion was from 10 degrees to 110 degrees. Atrophy was two and one-eighth inches, as compared with the opposite thigh. Except for a trace of abduction instability in semiflexion and slight anterior drawer action, the knee was quite stable. The patient cooperated well in performing the exercises.

At the end of *five months* there was rapid symptomatic improvement, which had been observed especially during the previous month. His only symptom was pain over the medial aspect of the knee on forced flexion. He could walk from five to ten miles, ran well, and was in considerable demand as a volleyball player. Moreover, in spite of a medical recommendation for a limited-duty assignment, he pleaded his way back to his former organization and had made three additional parachute jumps since leaving the hospital. Objectively, he still showed slight swelling, induration, and tenderness over the medial femoral condyle. Range of flexion was from 3 degrees to 130 degrees. There was atrophy of one inch. His gait was normal, both when walking and running. Stability was unchanged (Fig. 6). The disability rating was 1.5.

Six months after the injury a report was received from the Battalion Surgeon at the patient's new post. An extract from this report follows:

"Stability normal. . . . No abnormal abduction. . . . About 15 per cent. limitation of flexion. . . . Thigh measurements equal. . . . Slight joint enlargement of medial aspect of knee; no joint effusion. . . . Functional capacity is not yet normal, endurance is good, agility is fair. . . ."

Comment: Although surgical repair was initially recommended for this patient, he has had a very good result from the program of conservative immobilization. He shows the most pronounced picture of calcification about the tibial collateral ligament; but, aside from persistent local tenderness and limitation of flexion, this has not been associated with much clinical disability.

Abduction Injury with Delayed Quadriceps Recovery

CASE 5. A soldier injured his left knee in the opening shock of a parachute jump, when he somersaulted forward on leaving the airplane. After landing, he had severe pain along the medial aspect of the left lower extremity and was unable to walk. Upon admission to the hospital, he showed brush burns, not only on his boot, but also along the entire medial aspect of the left knee and left leg. He displayed severe abduction and anteroposterior instability of the knee, but the exact degree was not recorded. There was pain on any attempted motion, and tenderness over both tibial and fibular collateral ligaments. The routine roentgenograms, without special positioning, showed no abnormality of the knee except soft-tissue swelling.

The patient was immobilized in the sectional toe-to-groin cast for four weeks. At the end of this time, another toe-to-groin cast was applied without padding, holding the limb in nearly full extension. Immobilization was discontinued six weeks after injury, and physiotherapy and graduated activity were started.

Four months after the injury the patient still had severe symptoms; he limped on the toes of his left foot and showed about 5 degrees of limitation of extension. Flexion was possible to 120 degrees. There was one and one-quarter inches of atrophy of the left thigh. He was able to walk about two miles on pavement, but could not run; the knee swelled whenever he attempted to walk on uneven ground. Objective stability was good; there was only about 2 degrees of abduction instability in semiflexion, and slight anterior hypermobility.

After *six months* his condition was much the same, except that the swelling and limp had practically disappeared. The patient admitted having neglected all exercises. Atrophy was one and three-

FIG. 7-A

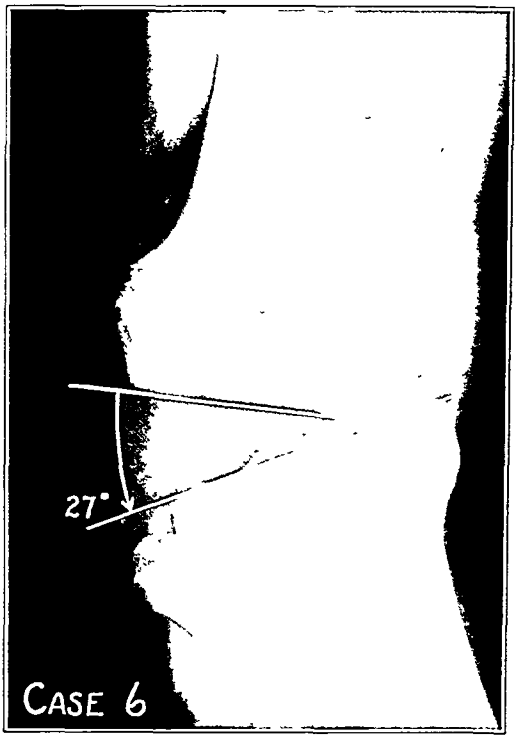

FIG. 7-B

This patient (Case 6) had extreme "adduction-plus-recurvatum" instability. The conventional roentgenograms in this case, without special positioning, showed no abnormality except soft-tissue swelling.

quarters inches. Flexion had improved to 135 degrees, but the knee remained weak and painful and felt unsteady on uneven ground. He got considerable relief from the medial heel wedge.

At the end of *eight months* the knee was improving slowly, but disability was still present. The knee ached at night after any exercise, such as carrying a suitcase for fifty yards. The patient's duties were largely sedentary, and the quadriceps exercises were being neglected. There was atrophy of one and one-eighth inches. There was no longer any swelling.

An examination at the end of *ten months* revealed that subjective improvement in the previous two months had been negligible. The patient had been taking no exercise at all, in spite of repeated urging. Atrophy had increased to one and one-quarter inches. Stability of the ligaments, however, was very good. The joint was completely stable in extension and showed only slight residual abduction in semiflexion. Anterior hypermobility was minimum. The persistent symptoms seemed disproportionate to the objective findings, which, except for the quadriceps atrophy, indicated an excellent result. Accordingly, the patient was returned to the hospital so that quadriceps exercises could be carried out under the supervision of the Reconditioning Service. His disability rating was 2.1.

At *eleven months*, after one month of supervised exercises, atrophy of the thigh had decreased to agility. The patient could walk over five miles and could trot half a mile; but he was unable to run rapidly without a limp. The continuous ache in the knee had subsided completely. He could walk ten miles without favoring the limb, and his only symptom was a slight pain beneath the patella when he ran on uneven ground. The patient was very much pleased with his recovery, and had enlisted for a term in the Regular Army. His disability rating was 1.4.

Comment: This case illustrates the parallel between clinical disability and quadriceps atrophy. It has been noted repeatedly that, when quadriceps exercises are neglected, the clinical improvement ceases. It should be mentioned that ordinary walking is not considered quadriceps exercise; neither is passive physiotherapy.

Adduction Injury with Recurvatum

CASE 6. A parachutist's right knee collapsed when he struck the ground violently, upon landing from a jump. He was unable to walk, and was brought immediately to the hospital with a diagnosis of possible fracture of the right lower extremity. Examination disclosed marked soft-tissue swelling and tenderness over the lateral aspect of the right knee, with striking instability, so that the limb could be adducted 30 degrees without undue pain. There was also a recurvatum instability amounting to 30 degrees. No abduction instability was noted (Figs. 7-A and 7-B).

The right lower extremity was immobilized in the sectional toe-to-groin cast for four weeks, with the knee in semiflexion and valgus correction; then a walking cylinder was applied and maintained for an additional four weeks, with the knee in nearly full extension. Upon removal of the cast, there remained moderate adduction instability, but no recurvatum. It was felt that the patient had regained maximum stability, and immobilization was accordingly discontinued. There was atrophy of one and one-half inches. Intensive exercises of the limb were started.

At the end of *three months* he walked without a limp and ran well for short distances, in spite of moderate residual adduction instability. There was still a tendency for the knee to swell after exercise. The range of motion was good; the patient could extend his knee completely and could flex it to 140 degrees. There was one and one-eighth inches of atrophy of the thigh.

Four months after injury the adduction instability measured 9 degrees by roentgenogram, but the patient had remarkably little subjective disability. His knee occasionally felt "loose" on twisting, but he could hike ten miles and could run 300 yards in forty-six seconds. He played a good deal of baseball and engaged in other sports. The knee showed no swelling or induration, and flexion had increased to 150 degrees. There was atrophy of three-quarters of an inch.

At the end of *six months* there was continued improvement. The patient claimed that his knee was stronger and steadier, although objectively the residual instability was unchanged. The range of motion was normal. There was atrophy of one-half inch. His only complaint was minor aching in inclement weather. The patient was pleased with the result and was quite active physically. His disability rating was 1.6.

Comment: Because of the considerable residual instability in this case, surgical repair of the fibular collateral ligament was considered after the cast had been removed; but the patient's functional improvement was so rapid, and the final disability so slight, that the operative procedure did not seem justified. Only three cases of adduction injury were encountered, but none of these patients seemed to be handicapped by the residual instability. As mentioned earlier, this is probably due to active muscle support of the tensor fasciae latae, which offers direct anatomical reinforcement for the injured ligament.

Complete Anterior Dislocation of the Knee

CASE 7. A parachutist landed in a ditch at night, dislocating his left knee. He was brought to the hospital in a Thomas splint, and showed clinical and roentgenographic findings of a complete anterior dislocation of the tibia. No circulatory or neurological abnormalities were observed.

The dislocation was reduced easily under pentothal anaesthesia, and the knee was immobilized in a padded toe-to-groin cast. This became loose after three weeks and was changed for a skin-tight toe-to-groin cast, which held the knee in almost full extension. Five weeks later the cast was removed; good stability was revealed, but there was pronounced stiffness and suprapatellar induration. After a trial of graduated activity, the induration showed no improvement, and the patient was returned to a walking cylinder for an additional three weeks. All immobilization was discontinued twelve weeks after injury.

Fourteen weeks after injury the patient still limped noticeably. The most striking clinical features were the persistent induration of the soft tissues about the front of the knee, and the limitation of flexion to 85 degrees. Stability was good; there was only slight abduction in semiflexion and slight anterior hypermobility. There was atrophy of one and one-eighth inches. The patient received graduated quadriceps exercises.

At the end of *four months* he could walk five miles and could trot a little. The knee tended to swell on excessive activity, but the induration was subsiding gradually. Flexion had improved to 100 degrees, and atrophy had decreased to three-quarters of an inch.

Five months after the injury the knee seemed stronger, and the patient could stand all day with minimum discomfort. Flexion was limited to 120 degrees, which prevented him from running normally. The residual instability remained as before, except that he now displayed a few degrees of recurvatum in the injured knee. There was atrophy of one-quarter inch.

Examination at the end of *six months* revealed continued improvement in strength, endurance, and agility. The patient could walk over five miles and could trot half a mile; but he was unable to run smoothly, because flexion was still limited to 120 degrees. He could run up and down stairs, two or three at a time. Excessive activity still provoked mild transient effusion. Roentgenograms disclosed Pellegrini-Stieda type of calcification near the medial femoral condyle. There was no change in stability. The thigh measurements were equal. The patient was taking long, cross-country bicycle rides to complete his rehabilitation. Disability rating was 1.7.

Comment: According to widely accepted indications, the more severe the injury, the more imperative is surgical repair. In view of the present clinical experience, however, this reasoning does not appear valid. Since conservative treatment yielded such good results in complete dislocation and in the extreme lateral instability illustrated by Case 1, there is ample justification for conservatism in the less severe injuries.

SUMMARY

1. Eighty-five cases of acute instability of the ligaments of the knee were treated by conservative immobilization.
2. Most of the patients were parachutists, who tore the tibial collateral ligament of the left knee during the opening-shock phase of the parachute jump.
3. The plan of treatment consists in immobilization in plaster-of-Paris, supplemented with intensive exercises for the thigh musculature.
4. End results are evaluated on the basis of the functional capacity of the knee, according to specific clinical criteria.
5. The most reliable single index of disability is the amount of quadriceps atrophy. Rehabilitation of the shrunken quadriceps invariably improves the functional capacity of the knee.
6. Recovery of stability has been very satisfactory. Ninety-five per cent. of the abduction injuries heal with less than 5 degrees of residual instability.
7. Calcification of the tibial collateral ligament is a frequent complication, but has not proved disabling.
8. Recovery of flexion and extension has been excellent.
9. Conservative immobilization has yielded excellent results in this series.

NOTE: This study was carried out under the supervision of Major Roy Ciccone, M.C., Chief of the Orthopaedic Section, Army Service Forces Regional Hospital, Fort Benning, Georgia, and the authors

wish to express their gratitude for his generous advice and assistance. Appreciation is also extended to the members of the X-Ray Department for their splendid cooperation. The mechanism of the opening-shock injury was illustrated by the Training Aids Section of The Parachute School, and the illustrations were reproduced by the Army Field Printing Plant and the Signal Corps Laboratory at Fort Benning.

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DISABILITY EVALUATION FOR THE HAND *

BY LIEUTENANT COLONEL DONALD B. SLOCUM AND LIEUTENANT COLONEL DONALD R. PRATT

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The fundamental premise of this paper is that appraisal of disability should be based upon function. The present systems of disability evaluation have evolved over a period of several years as a joint endeavor of the physician and the agency giving compensation. Through the efforts of such men as McBride, Kessler, and others, accurate and concrete tables have been formulated to cover a variety of conditions in the hand. For the case which duplicates the conditions found in the tables, their figures are adequate and workable. More complex problems, however, can be judged only by the most experienced observer. The novice or the moderately trained physician frequently finds himself lost in a maze of detail when studying these empirical formulae, and often his conclusion is the result of guesswork. The purpose of the present discussion is to present a simplified method of disability evaluation, based upon function, which incorporates the time-tested values set forth in the past.

Disability evaluation has a dual purpose: The first is its traditional use in the appraisal of an end result of trauma or disease for an insurance company or an industrial-accident commission. The second—and herein lies the most important medical obligation—is the determination of disability as a basis for planning treatment. In order to establish clear indications for prognosis, the physician must know what the present status of the hand is and what the result of treatment will be within the realm of reasonable expectancy. This will enable him to judge how worth-while the procedure is in view of the degree of improvement expected, the seriousness of the procedure, the time involved, and the economic status of the patient.

In this paper the authors are concerned with the hand alone; the remainder of the upper extremity is not considered. The three fundamental units of function in the hand itself are grasp, pinch, and hook.[3] These actions are fundamental, because they contain all the elements of power, motion, and dexterity used in any of the lesser activities of the hand. In the following discussion, certain values have been established arbitrarily for these functions on the basis of their relative importance. This has been necessary, since no precedent exists for formulating these values. They have simply been set down by the authors as their opinion of the relative importance of each function and may, of course, be changed with greater knowledge in the future.

Grasp may be defined as the combined action of the fingers against the opposed thumb and the palm of the hand. Its greatest use is in the last half of this motion, as grip is consummated. It is worth 50 per cent. of the value of the hand. Pinch is the apposition of the pad of the thumb against the pads of the opposing fingers. This is worth 30 per cent. of the value of the hand. Hook is simply what the word implies: The fingers are flexed so that their pads lie parallel and slightly away from the palm, forming a hook. This is worth 20 per cent. of the value of the hand. The modification of these values by sensory changes is explained in a later section.

The system of disability evaluation presented here is embodied in the chart shown as Figure 1. Certain radical changes from the standard methods will be noted:

1. All figures presented are in terms of the three primary functions of the hand: grasp, pinch, and hook.

2. The value given the little finger has been increased over that given the ring finger, because of its more strategic location in the hand. This polar position adds to the breadth and stability of the hand in grasp and hook.

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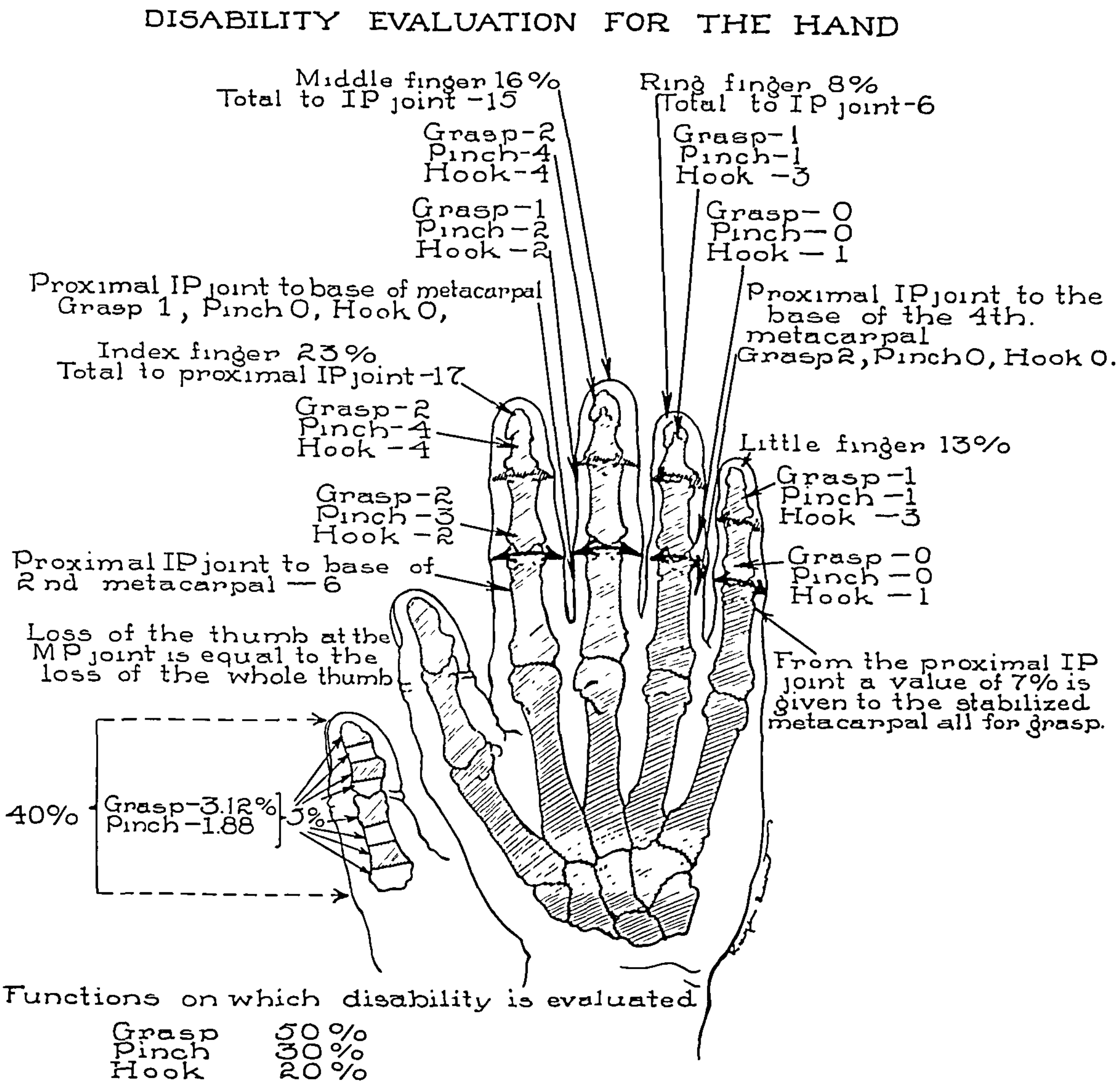

Fig. 1

3. Between the proximal interphalangeal joint of any one finger and the carpometacarpal articulation of that finger, any loss is given the same value.

The last statement demands some elaboration. In each finger, a different situation exists when there is an amputation above the proximal interphalangeal joint. For instance, amputation through the proximal phalanx of the index finger leaves a hand that still grasps well, in that the palm still forms a wide base against which the remaining fingers and thumb may clasp an object. This is a hand which, in many instances, may be perfectly satisfactory; but, on the other hand, the stump may impede the web and may also interfere with pinch, which is now carried out by the middle finger. If the metacarpal of the index finger is resected through its base, or if it is disarticulated, the web is left unhampered, so that pinch action may take place freely, and the appearance is improved. However, the stability of the grasp is diminished, due to the narrowing of the palm. In the middle finger and in the ring finger, amputation through the proximal phalanx leaves an unsightly hand with a space between the fingers during grasp. This is a decided handicap when small objects, such as a handful of nuts or beans, are to be picked up and held in the cupped hand. Grasp of larger objects, nevertheless, remains good. If the metacarpal is resected in one of these two fingers, the appearance is improved and the gap in grasp is closed; but a narrow and less stable hand results. When the little finger is amputated through the proximal phalanx, there remains adequate breadth for grasp and cupping, depending upon the mobility of the metacarpal. Some patients prefer amputation through

the metacarpal, however, because the appearance is improved and because this eliminates catching of the stump during such activities as reaching into their pockets.

It may be seen, therefore, that the degree of loss above the proximal interphalangeal joint does not alter the percentage of functional disability for all types of work. The improvement of one function is counterbalanced by the loss of another.

CHART OF DISABILITY EVALUATION

In the lower left corner of the chart (Fig. 1) are found the values for grasp, pinch, and hook. These are set arbitrarily at 50 per cent., 30 per cent., and 20 per cent., respectively. Above is the thumb, which is valued at 40 per cent. Since the thumb is one of the two major poles in grasp and pinch, this value was determined simply by taking one-half of the value of grasp (25 per cent.) plus one-half of the value of pinch (15 per cent.). The thumb is considered as a unit of function only from the tip to the metacarpophalangeal joint; proximal to this, all ability to grasp and pinch disappears. The inset drawing of the thumb demonstrates the values in amputation. Since the thumb is valued at 40 per cent., each quarter phalanx is valued at 5 per cent. Associated lesions, such as deformed nails, neuromata, painful cicatrices, *et cetera*, are evaluated by determining the extent to which they interfere with each of the major functions. An arrow pointing to the top of each finger indicates the value of that finger in terms of percentage of the hand as a whole. The distal interphalangeal joints are indicated by interrupted black lines. Solid black lines indicate the location of the proximal interphalangeal joints. Beside each phalanx, the percentile values of grasp, pinch, and hook are given, according to the importance of each of these elements. Below this is given the value from the proximal interphalangeal joint to the base of the metacarpal. One value is set for any loss in this region, when only a single finger is involved.

Use of Chart

In amputations, the following principles are used: In amputation of a single finger, the percentages of grasp, pinch, and hook of each phalanx are added to give the value of disability. If only a portion of the finger is lost, this value is apportioned to the nearest quarter of a phalanx. In amputations which include the proximal interphalangeal joint, the total value of the finger is used, regardless of whether the amputation is in the phalanx or in the metacarpal. In multiple finger amputations, the total is made up of the values for each phalanx lost. When the metacarpals for more than one finger have been amputated, however, the appraisal is made on the basis of the major function of the whole hand, as listed in the lower left corner of the chart.

Amputation of the thumb has already been described.

Lesions of the palm and the thenar eminence, and multiple involvement of the long tendons and their motors, are evaluated on the basis of alterations in the major functions of grasp, pinch, and hook. In instances other than amputation, the loss is judged according to the limitation in grasp, pinch, and hook which occurs in each finger.

Pain is evaluated according to the extent to which it interferes with each of the three major functions. Although pain is a subjective phenomenon, its results must be judged objectively. For example, an exquisitely tender neuroma in the pad of the thumb could eliminate all pinch in the hand (30 per cent.); affect grasp, through pain and awkwardness, so that the effective delivery of grasp would be only 10 per cent. instead of the normal 50 per cent.; and impair hook, due to loss of dexterity, so that its value would be only 15 per cent. instead of the normal 20 per cent. This would result in a residual value of the hand of 25 per cent. of normal.

Total loss of sensation is valued at 50 per cent. of the part. Thus a 50 per cent. loss of sensation would be valued as 25 per cent. disability of the part involved. In many in-

stances other disabilities are present, as well as loss of sensation. The rule in these cases is to determine in the usual manner the disability of the part on the basis of function. This is then the value of the disabled part. This figure is used to determine the value of the loss of sensation. For example, the middle finger is normally valued at 16 per cent. If the finger has been amputated in the mid-portion of the distal phalanx, the value of the disabled finger is 11 per cent. Associated nerve injury may have resulted in total loss of sensation in the remainder of the finger. Since sensation is valued as 50 per cent. of the part, there would be a further loss of 50 per cent. of 11 per cent., or 5.5 per cent.

In section of the median and ulnar nerves, and occasionally of the digital nerves, trophic disturbances may occur, which make the fingers or the hand useless, or partially useless, as far as function is concerned. Again in these instances, clinical judgment must be used in taking the major functions as a basis for evaluation.

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DISCUSSION

Lieutenant Colonel Lot D. Howard, Medical Corps, Army of the United States: The whole problem of disability evaluation is a tremendous one, and one which most of us know very little about. We compile a few measurements, make a few general statements on paper, and then feel content, knowing that someone else will get out some tables and calculate a percentile figure.

As if our own peacetime industrial accident work is not enough of a headache, we are now confronted by thousands of partially disabled war veterans, who will need disability evaluation and who will be remunerated on this basis.

I had the opportunity of visiting a Veterans' Hospital on the way to this meeting, and observed the struggle they are having to establish temporary disability ratings for crippled hands, often with inadequate or incomplete records, and without the opportunity of examining the soldier.

Colonel Slocum's chart for the determination of disability in the hand appears workable, but has not had to meet the test of time as yet. It is not simple; but it cannot be, due to its very nature. Minor points may give rise to differences in opinion, but these may be adjusted to the individual case.

In dealing with the hand, one must not lose sight of the fact that the hand is, and functions as, a unit; thus, what a man can do physically with his hand under living and working conditions is what counts.

A rating on the basis of carefully planned performance tests under the observation of a physician should be ideal, but here the personal equation on the part of both the patient and the doctor would lead to gross error and inconsistency.

Yet, to break down the hand for analysis of the function of its separate parts, and to calculate multiple percentages of percentages, ending at times with a decimal point and two figures, would be comparable to an aborigine looking at a pile of bolts, nuts, wheels, and rods, and trying to visualize a moving jeep.

Men who are familiar with disability evaluation are the first to admit the difficulty in arriving at a fair and unbiased appraisal. Yet some standard must be set. All are agreed that an objective approach, such as has been outlined, must be used; yet the admission of this constitutes the first error in the appraisal, since the same limitations, objectively measured, need not necessarily give the same disability to different individuals, even in the same occupation.

Colonel Slocum's contribution is limited to the hand; yet he knows, as we know, that the usefulness of the hand is dependent also upon the function of the arm and shoulder for positioning and stability.

In thinking about disability evaluation in general, one cannot help but be impressed by certain aspects of the problems which have wide economic and sociological application, as the following examples indicate: How much is a hand worth? Is one man's hand worth as much as another man's hand? How much is a man's hand worth, if the man has no value from the standpoint of the group? Should a man in one state get more compensation for a given disability than a man in another state? Should a veteran

get the same as a man in industry? Just what are we compensating for, and who pays the bill? Such questions could go on indefinitely, and you cannot find an answer for any of them.

The problem persists and warrants serious thinking on the part of all medical men Anyone undertaking such a difficult problem needs our encouragement; and criticism had best be reserved, unless something better can be offered.

I want to thank the authors for this opportunity to discuss their paper

Dr Earl D McBride, Oklahoma City, Oklahoma I am pleased that someone is interested enough in the subject of disability to venture an essay on this program Quite properly, Colonel Slocum has recognized 'function' as the true basis of evaluating disability Likewise, he points out that the functional reason for appraising the effect of disability on the body is to be able to judge the advisability of surgical procedures in terms of end results, and what they will mean toward loss or gain in function

"Disability is a transformation of body structures resulting in depreciation of normal ability to perform the functions of established physical accomplishments" Such a transformation may be the result of injury, disease, new growth, or malformation The period of existence may be temporary, progressive, or permanent It must be recognized that no two individuals develop function in the fingers, hands, or feet to exactly the same extent or proportion Therefore it is my opinion that any arbitrary assumptions of functional evaluation, such as Colonel Slocum has made—that the grasp of the hand is 50 per cent, the pinch 30 per cent, and the hook 20 per cent—are not fundamentally sound Actually, I think this is a very fair average assessment for each of the three functions However, if we are to arrive at a uniform standard in evaluating disability, we cannot very well assume arbitrary values We must, on the contrary, devise a dependable system, based on fundamental principles, as in other medical subjects

How can we say that the function of grasp should have the same value of 50 per cent for all hands? For instance, compare the hand of a laborer who digs ditches with the hand of one who has become skilled in using tools I believe we might even say that the function of grasp would be rated somewhat higher in the hand of an orthopaedic surgeon than in the hand of a gynecologist, or of an eye, ear, nose, and throat surgeon.

It has been my contention that the fundamental factors which create function should be the basis of measuring function, rather than arbitrary divisions applied equally to any individual's hand

What do I mean by fundamental divisions or factors of function? First, there is the factor of quickness of action, nimbleness, and speed of movement Second, there is coordination of movement,—that is, the smoothness and the steadiness of action, or we might say the dexterity or the synchronizing of movements, which may have been cultivated over a lifetime and may even mean the difference between ordinary use of the hand and expert use of it Third, there is the factor of strength The lack of strength often creates a necessity for unusual effort or strain Fourth, there is security of action,—that is, the confidence and dependence which one may have in the use of the part of the body When a part of the body has been injured, there is a lack of trustworthiness and reliability, so that the part cannot be used without a certain amount of conscious effort Fifth, there is the factor of endurance,—how long the individual can work with a disabled part

Most individuals have to work for a living and if we were measuring the capacity of the disabled individual as to his ability to perform labor, we would add two other factors One would be that of safety to himself and others as a workman, and the other would be the prestige of being found able-bodied in a pre-employment examination

By applying any estimated percentile value to each functional factor within a total of 100 per cent, one can arrive at a very reasonable conclusion as to the related value of disabled parts of the body

Returning to Colonel Slocum's scheme of disability of the hand, again I wish to commend him for his effort in this respect I think his arbitrary divisions are very accurately conceived Furthermore, I think his method is very easy for most of us to use It is especially adaptable to the purpose for which he recommends it,—namely, that of evaluating disability as a basis for planning treatment

No other part of the body requires such consideration as does the hand It is unique that he has evaluated the little finger more than the ring finger I believe he is perfectly correct in this observation Colonel Slocum's scheme is especially adaptable for evaluation of the hand when amputations are considered I believe it would be a little awkward to use it at times when various degrees of contractions and deformities are being considered for surgical improvement His evaluations are placed chiefly on the location of various points on the individual phalanges

From the standpoint of ankylosis and deformity, it is essential to base the elements of function upon joint action, more than upon bone deformity Here, again, coordination, strength, endurance, and other factors must take precedence in the mind of the one who makes the evaluation of such a hand

THE PROBLEM OF MENISCECTOMY IN THE SOLDIER

BY LIEUTENANT COLONEL W. ALEXANDER LAW

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Under Service conditions, injuries to the knee joint are as frequent as they are important; and they form a considerable source of sickness, with consequent hospitalization and loss of man power. A proportion of these injuries are meniscus lesions, and an attempt has been made in this series of cases to determine the value of operative treatment.

In a Base Hospital during the first six months of 1944, 120 "clean" knee-joint explorations were performed, and in 104 instances meniscectomy was carried out; of the remaining cases, missiles were removed from the joint in nine, loose bodies were removed in four, and nipping of enlarged infrapatellar pads of fat was found in three.

Careful selection of these cases was made in order to exclude those in which there were accompanying pathological changes,—such as osteo-arthritis, osteochondritis dissecans, undue laxity of collateral or cruciate ligaments, and gross wasting and weakness of the quadriceps muscle. These patients were regraded and treated by physiotherapy. The object of operation, therefore, was to keep the soldier in his category—usually that of the fighting man—and to enable him to return to full duties as rapidly as possible.

The problem is not quite the same as in civil life, where the patient requiring a meniscus operation is very frequently the athletic young man of good physique, with muscular development above the average. The British fighting soldier, although physically very fit, does not always have the muscle power of the first-class athlete; and yet, in the course of his training and actual fighting, he is subject to stresses and strains on the knee joint far in excess of those encountered in ordinary recreational activities. It is reasonable, therefore, to anticipate the necessity for a longer rehabilitation period in the case of the fighting soldier than in his civilian counterpart.

The initial injury occurred while the patient was playing football in fifty-six cases (54 per cent.); during military training or actual battle in twenty-three cases (22 per cent.); and as a simple accident, such as a fall or while kneeling at work, in twenty-five cases (24 per cent.). The strictly military causes included falls into bomb craters and diving for slit trenches (ten cases); jumping out of vehicles (three cases); blows from the starting handles of vehicles (four cases); parachute jumps (two cases); being caught and twisted in barbed wire (one case); and being blown over by blast (two cases). In one case a tiny missile had ripped the cartilage on its passage through the joint, and signs of internal derangement persisted until after meniscectomy, nine months later.

CLINICAL DATA

No patient in this series was submitted to operation unless it was clear that the disability was a real one and that the soldier was handicapped in performing his duties. The duration of history varied considerably, but all the patients had had recurrent attacks of instability and locking of the knee joint, alone or in combination; and the occurrence of at least an initial weight-bearing rotational strain on the flexed knee was always sought. This type of injury is indicative of a tear or detachment of the meniscus, as opposed to injury caused by abduction or adduction strain on the extended knee, which results in ligamentous damage.

Forty-four patients had a history of less than six months' duration; eighteen had a history lasting from six to twelve months; eighteen had a history lasting from one to two years; and twenty-four had a history of over two years' duration. The incidence of injury to the right and left knee was about equal,—fifty-three and fifty-one instances, respectively.

The medial meniscus was the site of the lesion in eighty-nine cases, and the lateral meniscus in only fifteen cases. One reason for this disparity is that the majority of patients with lesions of the lateral meniscus were not subjected to operation. This applied particularly to cases of cystic degeneration, where recovery is frequently prolonged and incomplete, so that downward grading is necessary. Therefore it is more satisfactory from the point of view of conserving both man power and hospital accommodations to reclassify these cases without operation. For similar reasons, patients with lesions of both menisci were not considered suitable for operative treatment.

Effusion and joint locking were rarely seen in these cases, both having resolved or been treated during evacuation to the Base Hospital, but McMurray's test was found particularly useful; the presence of an audible and palpable "thud" and the degree of knee extension at which this occurs not only confirmed the diagnosis but indicated the site of the tear in the meniscus. In some cases this entailed the use of diagnostic manipulation under pentothal anaesthesia.

Roentgenography was considered essential to exclude the possibility of loose and foreign bodies, missiles, or osteo-arthritic changes in the joint.

In a few cases where the degree of disability was in doubt, provocative physiotherapy was employed and careful observation was kept for the recurrence of pain, joint swelling, and locking. In all cases preoperative physiotherapy was used, not only to restore power and tone to the quadriceps muscle, but also to teach the patient the exercises necessary for him to perform after operation. The physiotherapist, too, was able to study the patient and gain his confidence,—both important adjuncts to rapid convalescence and rehabilitation.

OPERATIVE DETAILS

A complete skin preparation for forty-eight hours with flavine, an operative field rendered bloodless by applying an Esmarch bandage, and a non-touch technique were invariably employed. A horizontal incision, about one and one-half inches long, was made in the line of the joint. This incision extended from the region of the anterior horn of the meniscus to near the anterior border of the fibular collateral ligament; the ligament was always carefully avoided, although it could be inspected, if desired.

The whole meniscus was invariably removed. It has been stated that such a procedure injures the joint excessively and is not necessary. However, with the approach described, suitable narrow deep-bladed retractors, and a sharp meniscectomy knife, the trauma to the knee joint in freeing the whole cartilage is minimum, and unexpected lesions of the posterior horn are not missed. Tears of the posterior horn, either alone or in conjunction with other lesions, were found on nineteen occasions (18 per cent.) in this series, and double bucket-handle tears were discovered in three additional cases,—strong enough indication for total meniscectomy. In two cases a loose posterior horn, which remained after a previous operation elsewhere, was removed through a vertical incision behind the posterior margin of the tibial collateral ligament. That there was no undue trauma in these cases is also borne out by the fact that there was not one instance of postoperative effusion in the knee joint severe enough to require any relaxation of the knee bandage, far less aspiration of fluid from the knee joint.

After closure of the wound in layers, a firm dressing was applied and no back splint was used. The Esmarch bandage was removed after the knee bandages had been applied. Postoperative observation was made to exclude oedema from too tight bandaging and foot drop from pressure on the peroneal nerve at the neck of the fibula.

Quadriceps-contraction exercises were commenced the day after operation and continued daily, together with attempts at straight-leg raising and exercises with the leg partially supported. The dressing was untouched until the skin sutures were removed, on the tenth day; flexion exercises were commenced on the fourteenth day, when the patient was

allowed out of bed, wearing a crepe bandage. It is considered that, by confining the patient to bed for this period and avoiding knee flexion, sound healing of the suture line was encouraged; and that the bed exercises did not interfere with this healing, but were essential to maintain good tone and power of the quadriceps muscle.

From the second week onward, treatment consisted of a graduated course of physiotherapy, carried out primarily in the Hospital and finally at a Convalescent Depot. This consisted of static quadriceps exercises and the use of weights and pulleys to provide resistive exercises; and gradually advanced to remedial and general exercises, therapeutic games, and physical training. Massage and faradism were rarely employed, and then only in patients who were slow to develop ability to contract the quadriceps voluntarily. Such treatment was supplemented, and replaced as soon as possible, by active exercises. The interest and active cooperation of the patients are essential for speedy rehabilitation, which can be encouraged and maintained by grouping these patients in special wards and classes, thus developing a competitive spirit.

THE CARTILAGE LESION

The main types of injury found in the eighty-nine cases of medial meniscectomy can be grouped as follows:

	Number	*Per Cent.*
Bucket-handle tears	55	61.8
Peripheral detachment	12	13.5
Tears of posterior horn	13	14.6
Pedunculated fragments and tears of anterior horn	8	9.0
Cystic changes	1	1.1

This grouping, applied to the fifteen cases of lateral meniscectomy, is as follows:

Bucket-handle tears	4	26.7
Tears of posterior horn	1	6.7
Pedunculated fragments and tears of anterior horn	5	33.3
Cystic changes	5	33.3

The percentage incidence here is of little significance, as these cases were even more carefully selected for operative treatment.

Correlation of the initial accident with the type of meniscal lesion disclosed that football injuries produced the bucket-handle tear in both medial and lateral menisci, and that cystic changes in the lateral meniscus might be related to a blow in that region; but more frequently the patient could remember no real injury, the onset of the disability being insidious.

In a considerable number of the cases a large protuberant infrapatellar fatty pad was seen at operation, in addition to the cartilage lesion. When this pad showed signs of being nipped between the bone ends, with resultant bruising, hemorrhages, or the formation of fibrofatty tags or polyps, partial excision was performed. No ill effects were noted from this procedure in ten cases, although it might be expected that this additional intra-articular trauma would tend to increase postoperative effusion, or even result in hemarthrosis.

Less than half (five) of the posterior-horn lesions were attributable to football injuries. The majority resulted from a fall while traversing rough ground, either during training or in actual battle; but the character of the knee strain was similar to that incurred during a football injury and consisted of rotation on the flexed knee, the foot being supported and taking the body weight.

Where the lateral meniscus was torn or detached, a football injury was the initial cause in eight of the ten cases. No definite injury could be determined in the five cases of cystic change. One patient with cystic change in the anterior horn of the medial meniscus gave a history of an initial twist of the knee at football, six months before, followed by frequent recurrences of pain, swelling, and locking.

Evidence of osteo-arthritic changes in the knee joint was seen at operation on four occasions. Three of these patients had histories of longer than two years' duration and were regraded before completing convalescence, but the fourth patient retained good function and an A category.

Osteochondritis dissecans was noted at operation in three other cases, and, although recovery was normal, reclassification was carried out; the joint was regarded as unsuitable for severe stress and strain.

The occurrence of a bursa around the lateral head of the gastrocnemius was noted in two cases, but subsided in the course of physiotherapeutic treatment and appeared to leave no ill effects.

In one patient thrombophlebitis developed in the calf, and this necessitated longer convalescence and downward grading.

RESULTS OF TREATMENT

The average time spent in the Hospital after operation for all the patients in this series was thirty-four days. In the fourteen patients who completed their treatment in the Hospital and did not go to the Convalescent Depot, the average time taken in returning to duty was forty-five days.

The length of the history of disability—whether less than six months or over two years—made no appreciable difference in this postoperative recovery rate, but frequently patients with a longer history required a longer course of preoperative physiotherapy and therefore a longer total period in the Hospital. An average figure for total hospital stay would not be pertinent in this series, as in many instances several weeks were spent in evacuation, with little or no preoperative treatment. The cases of cystic lateral meniscus had a slower recovery rate, requiring on an average forty-five days in the Hospital before final rehabilitation.

No ill effects from the horizontal incision were noted or reported from the later follow-up. A few patients had anaesthesia and numbness in the infrapatellar region shortly after operation, but all signs of this had disappeared in from six to twelve weeks and no neuroma was reported to have developed. There was no case of wound or joint infection.

The power of full flexion of the knee had returned in nearly all the cases within from twenty-one to twenty-eight days, but the length of final rehabilitation was in direct proportion to the degree of wasting and weakness of the quadriceps muscle. The average time taken to attain fitness for duty, including treatment at a Convalescent Depot, was fifty-four days. Making allowances for time spent at Training Depot or Reinforcement Center, the total period of absence from duty in the forward area would amount to approximately eighty days. The standard of fitness required for return to duty was a knee joint free from pain, swelling, or undue laxity, with full quadriceps power and full range of flexion and extension. In addition, the confidence as well as the ability to attempt the assault course, a fifteen-mile route march, and a cross-country run were essential.

Twenty-five patients failed to attain this standard. Twenty cases were graded downward into a disability category allowing only moderate stress and strain and five cases into a disability category for base duties only. The main cause of failure (in seventeen cases) was persistent quadriceps wasting, which responded very slowly to intensive treatment. Osteo-arthritis and osteochondritis dissecans each accounted for three cases of regrading, and ligamentous laxity accounted for two cases. It is considered that even more strict selection of the cases for operation is necessary to reduce this figure.

Of the patients who returned to front-line duty, the majority were infantrymen or gunners; and it was possible, one and two years later, to follow fifty-four such cases still further. In six instances there had been recurrence of pain, swelling, and instability of the knee joint sufficiently severe to necessitate hospital treatment.

These symptoms were produced by such relatively minor traumata of a twisting nature as resulted from jumping into trenches, walking over rough ground, or playing football. The author was fortunate enough to see three of these patients, and to obtain reports on the remainder. Without exception, the disability was due to a weak quadriceps muscle, and the symptoms abated promptly on treatment by physiotherapy.

These patients returned to duty and maintained their categories, but it would appear likely that in the course of time a certain number will have knee joints which are more susceptible to minor injuries; if this weakness cannot be overcome by further development of the quadriceps muscles or if the symptoms tend to recur frequently, regrading will be necessary, thus increasing still further the percentage of failures.

CONCLUSIONS

Meniscectomy is an operation of value in the soldier only in carefully selected cases of internal derangement of the knee joint. Under campaign conditions the operation is not justified in the presence of osteo-arthritis, osteochondritis, or weakness of ligaments or muscles.

Total meniscectomy is preferable in order to exclude multiple meniscus lesions, and does not appear to cause excessive operative trauma to the joint.

Preoperative and postoperative physiotherapy are of as great importance as operative technique.

The majority of patients can be expected to be fit for duty within two months after operation, but in actual practice, for troops in the forward area, three months' absence from the unit is to be expected.

NOTE: The author's thanks are due to Brigadier Harold Edward, Consulting Surgeon, and to Lieutenant Colonel A. J. Watson, R.A.M.C., Adviser in Orthopaedics, for their unfailing help and advice; and to the nursing and physiotherapy staffs of the British General Hospitals, where these cases were treated. The patients themselves responded loyally to follow-up requests, and Major C. D. Kelly, R.A.M.C., at a Convalescent Depot, very kindly supplied useful case details.

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EXPERIENCES WITH THE BRITTAIN ISCHIOFEMORAL ARTHRODESIS *

BY JOSEPH A. FREIBERG, M.D., CINCINNATI, OHIO

From the Orthopaedic Department of the College of Medicine, University of Cincinnati

For a number of years the writer has been dissatisfied with the rather high incidence of failure of osseous fusion following the use of the standard iliofemoral operations, especially in the tuberculous hip. Frequently, osseous fusion has not been accomplished, even after a second operation. Other surgeons have had similar experiences. In 1942, Badgley and Hammond published the end-result study of seventy-one cases in which fusion operations had been performed on tuberculous hips. They reported osseous ankylosis, requiring an average time of five years, in 52 per cent. An additional 22 per cent. of the patients had satisfactory results, but with fibrous ankylosis and variable symptoms. The failure of the iliofemoral operation has been due to the distraction effect of the adductor muscles on the superiorly and laterally placed graft; and, in some cases, to the presence of diseased bone in the superior portion of the acetabulum.

Brittain has pointed out that the mechanical strength of the ischiofemoral strut graft, placed inferior to the hip joint, is superior to that of the flying-buttress graft of the iliofemoral type. The former heals under a compression force, while the latter must heal under tension; the force in both instances is supplied by the adductor muscles of the hip and thigh.

Healing of tuberculous lesions of the hip has been reported by Kofmann and Tarlo, in 1935, and by Farkas, in 1939, as being hastened by subtrochanteric osteotomy. This operation allows the adductors—at least temporarily—to immobilize the hip joint without the sacrifice of a good functional position for fusion of the limb as a whole. Bosworth, in 1942, reported nine cases of tuberculous disease of the hip joint, treated by ischial transplantation of the proximal end of the distal femoral fragment after a subtrochanteric osteotomy. Of the nine patients, osseous ankylosis developed in five, two died, fusion failed in one, and one had been operated upon too recently for the end result to be known. Brittain has ingeniously combined the intertrochanteric osteotomy with the ischial transposition of the femur, reinforced and stabilized by a massive tibial graft to supply osteogenic substance. It is of interest that Brittain reported his first operation on February 20, 1936, and Bosworth his first—without the graft—in December 1936.

Brittain reported thirty-five cases of ischiofemoral arthrodesis,—nineteen in tuberculous disease of the hip. Of these, 80 per cent. healed by osseous fusion after the first operation, and an additional 8 per cent. healed by subsequent surgery. Knight and Bluhm have reported nine cases of Brittain ischiofemoral arthrodesis for tuberculous hips; twelve operations were performed, because three cases were bilateral. Two of these cases were too recent to permit end-result studies. Of the seven cases in which results after one to two years were available, ten operations were represented. In six, osseous ankylosis took place; two grafts fractured; one graft was absorbed distally; and one graft was involved by the infection, but was healing.

The author performed seven Brittain ischiofemoral arthrodeses in a period of seven months—from April to November 1944—and waited six months to determine the results in these cases, prior to continuing this operative procedure. Although numerous additional operations have now been done, end-result studies are reported only for the seven patients operated upon from thirteen to twenty months previously. Of these, six were patients with tuberculous hips, whose ages varied from seven to eighteen years; five had proved tubercu-

Fig. 1-A

Fig. 1-B

H.D., male, aged twelve years. Patient had proved tuberculosis of left hip, with quiescent abscess
Fig. 1-A: Preoperative roentgenogram.
Fig. 1-B: Roentgenogram sixteen days after operation.

Fig. 1-C

Fig. 1-D

Fig 1-C: Roentgenogram, seven months after operation, shows fusion.
Fig 1-D: Seventeen months after operation. Patient was walking without support at seven months.

lous lesions. One patient, a woman of fifty-three, had a painful, disabling, degenerative arthritis following an ancient traumatic luxation of the hip.

RESULTS

Of the six patients with tuberculous hips (Table I), the results after ischiofemoral arthrodesis were as follows: Two patients (H. D. and M. M.) showed osseous fusion, clinically and by roentgenogram (Fig. 1-C), in seven months; one (A. J.) showed osseous fusion in eight months (Fig. 3-A); and one (S. C.) in nine months. In other words, fusion occurred in two-thirds of the patients in nine months. In one patient (N. K.), an incorrigible seven-year-old girl who broke her spica one month after operation and four times subsequently in the first five-month period after operation, firm fibrous union developed. She was asymptomatic and ambulatory, without support, sixteen months after operation. Now, three months later, she is still doing well. It was thought that in this instance the osteotomy alone hastened healing of the disease. In the sixth patient (R. N.), a woman twenty-two years old with a quiescent pulmonary lesion, renal tuberculosis developed one

month after operation. The spica was removed to make retrograde pyelograms at the end of four months; and again, eight months later, when a nephrectomy was done. Now, one year after the Brittain ischiofemoral operation, the hip has minimum motion clinically, and roentgenograms indicate apparent healing.

The one non-tuberculous patient (Sister P.), a moderately obese woman of fifty-three who had painful, disabling, traumatic arthritis of the hip, showed clinical and roentgenographic fusion in four months (Fig. 6-B); she had been up on crutches two months after operation. This patient walks with an almost imperceptible limp, sits well, and can kneel and again assume the upright position without assistance or unusual effort. Her hip is fused in 40 degrees of flexion, 20 degrees of external rotation, and 5 degrees of abduction.

Data concerning five of these patients—and the patients themselves—were presented at the meeting of the Clinical Orthopaedic Society in Cincinnati, October 1945, and the author believes it was generally agreed that the ischiofemoral fusions produced function as good as, if not better than, the fusion obtained by the iliofemoral procedures.

Fig. 2-A

M M, female, eighteen years of age Roentgenogram shows tuberculosis of left hip of eleven years' duration; right hip was normal

OPERATIVE TECHNIQUE

The operative technique carried out has, with minor variations, been that described by Brittain in his book. In tuberculous patients, surgery has not been performed in the presence of active abscesses; and, as in the past, surgery has been postponed until the patient has shown an ability to control the tuberculous disease by conservative therapy.

With the patient on a fracture table, both lower extremities are fixed, with the diseased member as

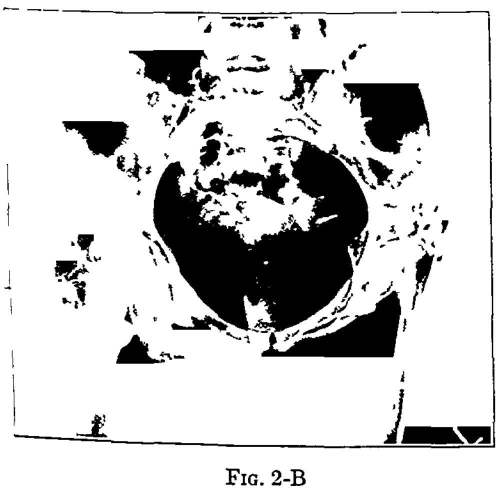

Fig. 2-B

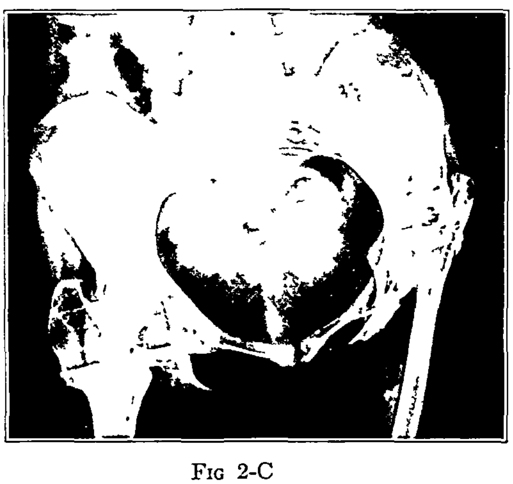

Fig 2-C

Fig. 2-B: Shows proved tuberculosis of right hip, with abscesses of three years' duration. Conservative therapy was employed.

Fig. 2-C: Shows fusion of right hip, fifteen months after operation; weight-bearing had been possible for four months. Note intra-articular healing.

TABLE I

END RESULTS, THIRTEEN TO TWENTY MONTHS AFTER OPERATION, IN SIX PATIENTS WITH TUBERCULOUS HIPS AND ONE WITH TRAUMATIC ARTHRITIS

Patient	Age and Sex	Diagnosis	Onset of Disease	Brittain Operation	Fusion	Complications	Comments
H.D.	12 M	Tuberculosis left hip with quiescent abscess. Guinea pig positive.	May 1940	Apr. 8, 1944 Left hip. Right tibial graft.	Clinically Apr. 29, 1944 By x-ray Nov. 15, 1944	None	Fused in 7 mo. At 10 mo. full weight-bearing allowed. Asymptomatic.
M.M.	18 F	Tuberculosis left hip; extensive atrophy and shortening.	1932				
		Tuberculosis right hip; recently healed abscess. Bacilli on direct smear.	Apr. 1941	May 1, 1944 Right hip. Right tibial graft.	Clinically Sept. 15, 1944 By x-ray Dec. 4, 1944	None	Fused in 7 mo. Full weight-bearing, asymptomatic, 11 mo. after operation.
S.C.	7 M	Tuberculous spondylitis, 3rd and 4th lumbar vertebrae.	June 4, 1941				Vertebrae fused spontaneously.
		Tuberculosis right hip. Tuberculosis left hip.	Dec. 26, 1941 Apr. 4, 1942	May 6, 1944 Right hip. Right tibial graft.	Clinically Feb. 21, 1945 By x-ray Feb. 21, 1945	Graft high, into diseased area; partial absorption.	Fused in 9 mo. Patient still recumbent.
N.K.	7 F	Tuberculosis right hip with sinus. Tubercle bacilli on direct smear.	Oct. 24, 1941	May 8, 1944 Right hip. Right tibial graft.	No osseous fusion.	Five broken spicas during first 5 mo. after operation.	Fibrous healing, 16 mo. Jog of motion Sept. 10, 1945; no fixation since. Asymptomatic Dec. 10, 1945.
A.J.	17 M	Tuberculosis left hip.	Mar. 1943	Aug. 19, 1944 Left hip. Left tibial graft.	Clinically Apr. 25, 1945 By x-ray Apr. 25, 1945	Nov. 10, 1944 Some bone absorption, ischial portion graft; later recalcified.	Fused in 8 mo.; weight-bearing begun. One year after operation, walking without support; asymptomatic.
R.N.	22 F	Tuberculosis right hip. Pulmonary tuberculosis, quiescent.	1941	Nov. 11, 1944 Right hip. Left tibial graft.	No osseous fusion.	Right renal tuberculosis Dec. 1944. Right nephrectomy July 31, 1945. Cast removed for pyelograms 4 mo. after fusion.	One year after fusion, hip fusing in spite of nephrectomy, etc. Still in spica.
Sister P.	53 F	Traumatic arthritis right hip; old luxation. Disabling pain.	1921	Sept. 21, 1944 Right hip. Right tibial graft.	Clinically Dec. 14, 1944 By x-ray Feb. 21, 1945	Obesity	Fused in 5 mo. Weight-bearing in short spica 4 mo.; without spica, 5 mo. Asymptomatic. Excellent function: kneels, etc.

Fig. 3-A

Fig. 3-B

A.J., male, seventeen years of age, had tuberculosis of left hip.

Fig. 3-A: Roentgenogram taken after seventeen months of conservative therapy.

Fig. 3-B: Shows left hip, eleven months after operation; fusion had been demonstrated, clinically and by roentgenogram, for three months. Patient was bearing weight.

Fig. 4-A

Fig. 4-B

S.C., male, seven years of age.

Fig. 4-A: Shows tuberculous spondylitis of third and fourth lumbar vertebrae; tuberculosis of right hip of three years' duration; and tuberculosis of left hip of two years' duration.

Fig. 4-B: Shows right hip, immediately after operation. Graft was too high and too long.

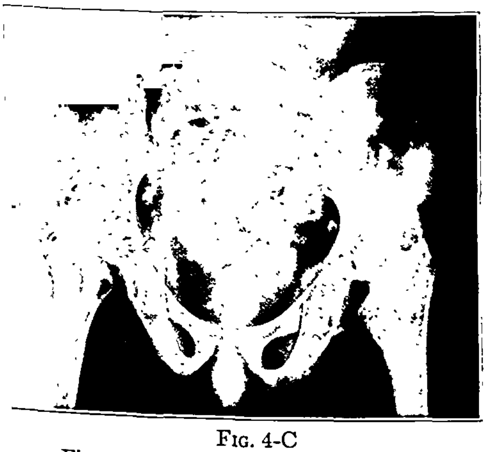

Fig. 4-C

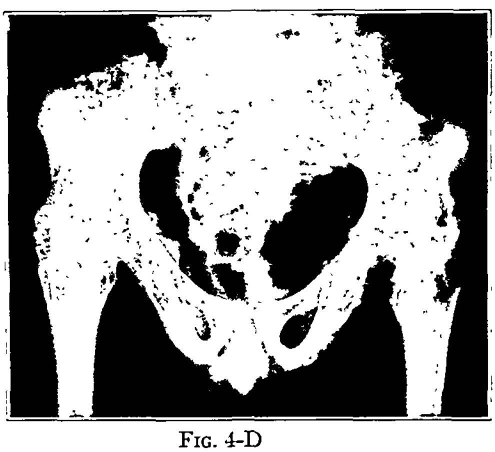

Fig. 4-D

Fig. 4-C: Three months after operation; graft being absorbed proximally.

Fig. 4-D: Fifteen months after operation; ischiofemoral fusion and intra-articular fusion have occurred.

nearly as possible in the ideal position for ankylosis. Two skin clips are applied,—one over Poupart's ligament at the junction of the middle and proximal thirds, and a second *anteriorly*, just below the inferior border of the greater trochanter. While a film on a portable machine is being taken and developed, a full-thickness tibial graft from the same leg is removed with a bone saw; the entire flat surface and the medial and anterolateral surfaces of the tibia are included, as is done by Brittain. The length of the graft varies with the size of the patient, and may be from three to five inches. The tibial wound is closed; the periosteum may be approximated easily because of the size of the graft removed. Through a lateral incision, beginning at the middle of the greater trochanter and carried distally about three inches, the periosteum of the femur is split longitudinally, retractors are inserted, and the lesser trochanter is identified blindly with a narrow blunt dissector. With the skin clips and roentgenogram as guides (Fig. 7-A), a three-sixteenth-inch drill is inserted about an inch below the greater trochanter and directed, proximal to the lesser trochanter, in a plane planned to meet the base of the ischium, the pubis, or healthy subacetabular bone; this plane depends upon the degree of bone destruction, the angle of the proposed fusion, and variation in the specific osseous anatomy. Another roentgenogram is made. A cleanly cut intertrochanteric osteotom yis now done; one of two identical osteotomes is used, with graduated quarter-inch scales marked on the narrow edge of the one and one-eighth inch blades. The osteotome is pushed gently but firmly medially in the *coronal plane* until bony contact is made, and is driven a short distance farther. Usually this is a distance of from one to one and one-half inches from the medial border of the femur. A third roentgenogram is now made. If the position of the osteotome is correct (and

Fig. 5-A

N.K., female, seven years of age. Roentgenogram shows proved tuberculosis of right hip, with healed sinus.

Fig. 5-B

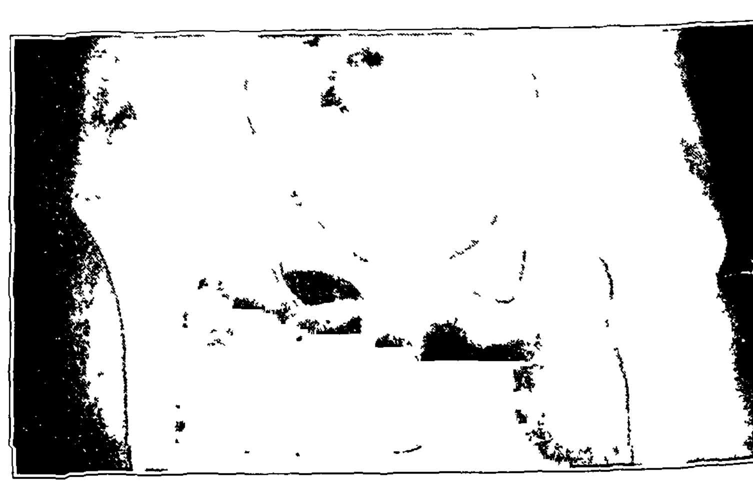

Fig. 5-C

Fig. 5-B: Shows right hip, soon after operation; graft was rather high, with too little displacement of femur.

Fig. 5-C: Thirteen months after operation *fibrous healing* had occurred, without symptoms. Cast had been broken five times in first five months after operation.

it usually is), with moderate traction on the limb, the second osteotome is placed on top of the first and, with the scale of the first osteotome as a guide, is driven into the ischial bone for a distance of from one-half to one and one-half inches, depending upon the size of the patient. The second osteotome is withdrawn and the tibial graft, with its medullary surface down and its proximal end beveled, is inserted along the surface of the first osteotome. After the graft touches the pelvic bone, it is driven in solidly. The first osteotome is now withdrawn. While some traction is maintained on the leg, *without increasing the abduction,* the proximal end of the distal fragment is displaced medially until contact with the bone is felt; a wide bone impacter is used. Following this simple procedure, the author has experienced no difficulty in displacing and maintaining the distal fragment medially transposed. The medial cut in the femoral periosteum produced by the osteotome has sufficed in more than a dozen operations, and there has been no indication that the periosteum also needs to be severed by a scalpel, as suggested by Knight and Bluhm. While the wound is being closed in a routine manner, a final roentgenogram is made. A long single spica or a double hip spica is applied, which includes the foot and extends to the mid-thoracic level. The tibial graft is removed from the same limb upon which arthrodesis is

FIG. 6-A

Sister P., female, fifty-three years of age. Patient had painful traumatic arthritis of right hip, of twenty-three years' duration.

FIG. 6-B

FIG. 6-C

Fig. 6-B: Four months after operation there was clinical and roentgenographic fusion of right hip, with full weight-bearing.

Fig. 6-C: Note massive fusion of right hip, one year after operation. Functional result was excellent.

being performed; no protection of the other limb is necessary. The fused hip is surprisingly stable at the completion of the operation. The lessened discomfort occasioned by a single spica, especially in an adult, and the stability of the hip have warranted its use in several instances.

The relative positions of the intertrochanteric area of the femur and the ischium are

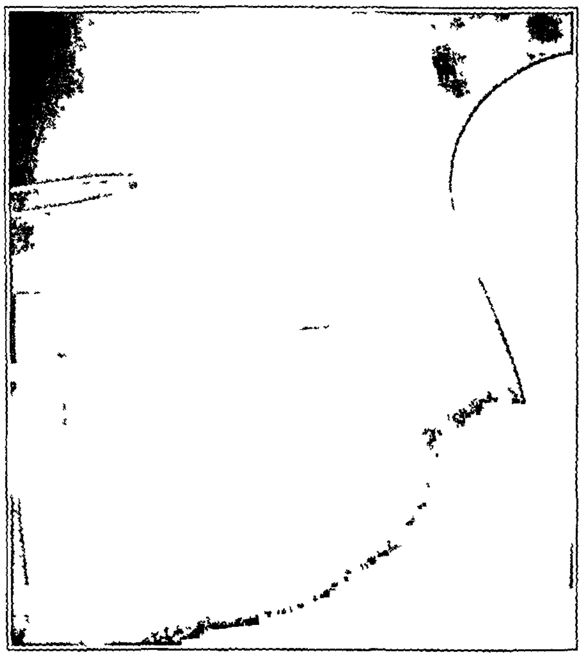

FIG. 7-A

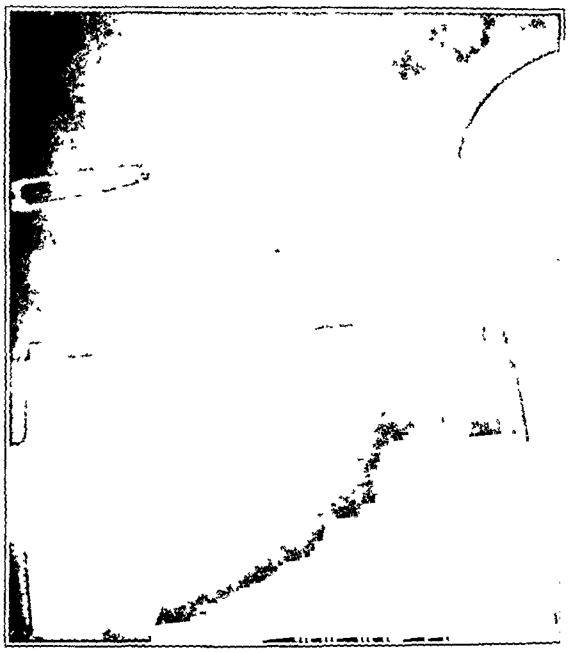

FIG. 7-B

L.G., female, twenty-two years of age.

Fig. 7-A: Patient had painful posttraumatic aseptic necrosis of right hip. Shows guide drill and skin clips used during surgery.

Fig. 7-B: During operation, osteotome has replaced guide drill.

FIG. 7-C

One and one-half months after operation, graft and femoral apposition are ideal. Callus is forming along graft.

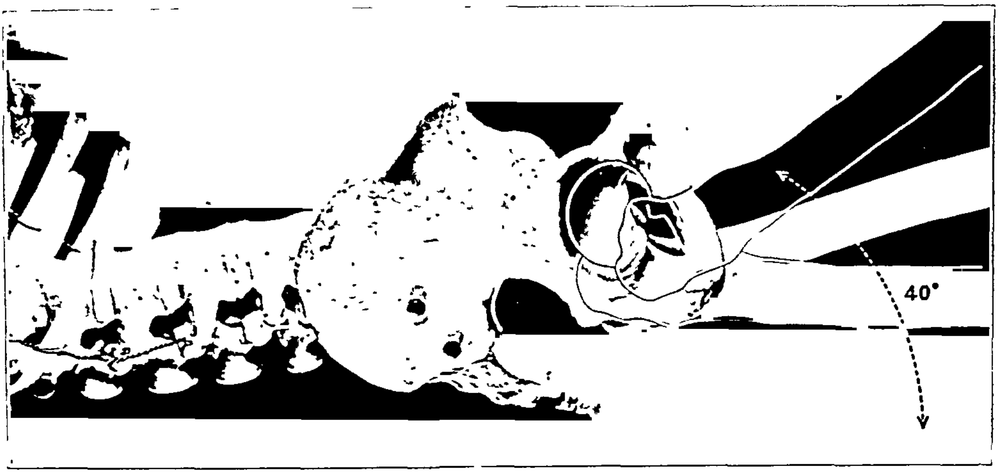

Fig. 8

Photograph of skeleton, with left femur moderately flexed. Tracing of right femur in approximately 15 degrees of external rotation. For children, with hip in extension, intertrochanteric area in coronal plane overlies ischium. For adults, with hip flexed 40 degrees, intertrochanteric area partially overlies ischium. Note obliquity of obturator foramen. A graft, the full width of the tibia, would strike the ischium or pubis, but could not enter the obturator foramen without coming into contact with bone, if introduced in the coronal plane.

Fig. 9-A

Fig. 9-B

R.T., male, forty-five years of age.

Fig. 9-A: *Shows Charcot hip, before operation.*

Fig. 9-B: Two months after operation. Patient had postoperative bilateral oedema of lower extremities and pelvis; cast was radically split; and graft and femur shifted spontaneously. Nevertheless, osteotomy is healing, and graft is viable. If fusion fails, hip should be stable.

own in Figure 8. With the lower extremity rotated externally 20 degrees for ideal function, the trochanter lies posterior to the plane of the femoral head and to the acetabulum. In children the hip is fused in extension, with allowance for some flexion to develop during subsequent growth. In adults, with the femur flexed about 40 degrees, the intertrochanteric area—or site of osteotomy—in the coronal plane overlies approximately the anterior third of the ischium. In the coronal plane, the full-width tibial graft is wider than the obliquely situated foramen. Therefore, if the osteotome and graft should fail to come into contact with the ischium, they must meet either the subacetabular bone or the base of the pubis. Free, non-osseous entrance into the obturator foramen has not occurred.

DISCUSSION

The basic principles of the Brittain ischiofemoral operation are simple. An adequate, rigid tibial graft must be firmly implanted in healthy pelvic bone. The proximal end of the distal femoral segment must be displaced medially to the ischium, so that new bone need not develop across a dead space bridged only by the graft. Uniform contact between the cut surfaces of the femur and the graft ensures moderate immediate fixation, early healing, and maintenance of the original operative position. If the hip joint has limited mobility at the time of operation, satisfactory apposition of the femoral surfaces and the graft should not be sacrificed in an attempt to perfect the angle of the fusing hip. This is the principle followed in the treatment of any fracture,—traumatic or surgical. Early release of the external fixation, whether accidental or intentional, may jeopardize the end result. The only instance in the author's experience where the graft became displaced was after a drastic splitting of the spica, two weeks after operation; it was indicated by extensive oedema of both lower extremities, extending up to the waist. This was in the patient with a Charcot hip (R. T.). Following the disappearance of the oedema, a new spica was applied. Although the graft became somewhat displaced, two months after operation fusion appeared to be developing (Fig. 9-B).

In patients with tuberculous lesions, the osteotomy should obviously be done at a level and at an angle which will allow the graft to be imbedded in bone not involved in the infectious process. In one patient (S. C.), partial absorption of the graft (Fig. 4-C) followed apparent extension of the disease from the acetabulum into the graft. In this instance, however, the end result was a satisfactory osseous fusion.

There is no need for a great degree of obliquity of the osteotomy; rather, a firm apposition of the femoral fragments with the graft and satisfactory imbedding of the graft should be sought. Depending upon the specific relations of the damaged hip joint, the angle of osteotomy should vary from the transverse plane to an angle of 45 degrees.

Although end results are reported on only seven cases, the high percentage of osseous fusion obtained, the relative simplicity of the operative procedure, and the absence of shock have convinced the writer that this Brittain method of performing hip-fusion operations should be given an extensive trial by orthopaedic surgeons. The indications for Brittain ischiofemoral arthrodesis are multiple; one of these is in Charcot's hips, which were previously amenable to arthrodesing operations only in the earliest phases of the disease. The contra-indications for this operation occur in those few instances where diseased bone cannot be "short-circuited" by the osteotomy and graft. One such tuberculous hip has been encountered during the past year, with a large calcifying abscess situated between the intertrochanteric area of the femur and the ischium.

CONCLUSIONS

Of six patients with tuberculous hip joints upon whom the Brittain ischiofemoral arthrodesis was performed, osseous fusion developed in four within from seven to nine months. In one case, with postoperative extraneous complications, fusion is apparently taking place after one year. In one adult, a painful, disabling traumatic arthritis of the hip was healed by osseous fusion in four months. Additional patients * upon whom this operation has been performed are showing every evidence of a similar high percentage of osseous fusion.

The Brittain ischiofemoral arthrodesis ideally combines an intertrochanteric osteotomy, which allows temporary joint rest, and an inferiorly placed strut graft; healing occurs under compression stresses, rather than tension stresses, as in the iliofemoral operations.

* Since this paper was prepared six additional Brittain fusions have been done, with results as satisfactory as those reported.

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DISCUSSION

DR. CARL C. CHATTERTON, ST. PAUL, MINNESOTA: I am sure we have enjoyed this excellent paper of Dr. Freiberg's, describing a good arthrodesis, extra-articular, of the hip joint; and it is my belief that, in the future, a greater number of extra-articular fusions of the hip joint will be of this type.

At the Gillette State Hospital, a Minnesota institution for crippled children, from July 1, 1924, to December 10, 1945, forty-six arthrodeses of the hip have been done. We find in this number that four were the Albee type, three were the Brittain type, one the Henderson type, nine the Hibbs type, and twenty-nine the Wilson type of fusion. Of these forty-six fusions, seven were refusions.

There was one case in which a fibrous fusion of the hip was progressing satisfactorily; therefore, there were really thirty-nine cases taken care of, with seven refusions and one hip which was still not stable.

At this Institution the time spent in the Hospital is not especially considered. All of the patients remained until their hips were in satisfactory condition; and the interesting thing to me was the deformity which took place, in spite of bony arthrodesis. We find in going over the cases that there were ten which required osteotomy for correction of deformity,—that is, of flexion and adduction. No patients have died as a direct result of the operation, but three have died since the date of operation.

In all of these cases except two, the arthrodeses were done because of a tuberculous condition.

I do believe that the point which Dr. Freiberg makes in his paper—namely, that the adductor muscles help stabilize the graft—is a very important consideration; practically all of the cases taken care of at Gillette Hospital which required operation for deformity were for deformity of flexion and adduction, especially adduction. There are several patients walking around with their hips flexed as much as 45 degrees, upon whom operation has not been done. Therefore, I can only recommend the Brittain operation after our experience with three patients whose hips have remained in excellent position.

Upon further reviewing the cases, we find that we had incomplete fusions after five Wilson operations and two Albee operations. The Hibbs operation in nine cases resulted in fusion in every instance. One of the Brittain operations did not produce solid fusion, but I felt that the time period had been too short for us to be absolutely sure that union was not going to take place. The record also shows that the greater number of Wilson operations were done on children under ten, while the Hibbs and Albee operations were done on older children. Of course, the Brittain operation can be done at any time, practically regardless of age.

I do believe at this time that the Brittain operation is the best extra-articular fusion for securing an ankylosis in tuberculous disease of the hip joint.

DR. ROBERT A. KNIGHT, MEMPHIS, TENNESSEE: Dr. Freiberg has brought to our attention a valuable method for inducing arthrodesis of the hip joint. Its advantages are many and its disadvantages and complications are relatively few.

Some of the complications in connection with this procedure have occurred in regard to the following points:

1. *Improper Selection of Cases*: The chief contra-indication in this respect has been the occasional case in which there is downward extension of the tuberculous process into the ischium. Also, one case of tuberculosis of the hip joint with an associated tuberculosis of the trochanteric bursa was not considered satisfactory.

2. *Improper Insertion of the Graft into the Ischium*: In one instance, the tuberculous disease involved the graft as a result of insertion of the graft into the diseased portion of the ischium. A sinus

formed, and secondary infection followed. Fortunately, involucrum formation eventually proved adequate to give a solid ischiofemoral arthrodesis, despite sequestration of a portion of the graft.

3. *Incomplete Medial Displacement of the Shaft of the Femur Against the Ischium*: Complete medial shifting of the shaft hastens consolidation of the fusion mass, which consists of the ischium, graft, and proximal end of the femur, and reduces the strain upon the graft. The strain from incomplete medial displacement has been responsible for fracture of the graft and for absorption about the outer end of the graft, which took place in our early cases, where displacement was incomplete. These complications greatly prolonged the period of necessary immobilization after operation.

My experience with this method has been almost entirely confined to cases of tuberculous disease of the hip joint, but its use in other types of disease of the hip joint requiring arthrodesis is apparent. It is probably the most rational and practicable method of obtaining arthrodesis in Charcot's disease of the hip joint, and I am most impressed with Dr. Freiberg's use of it in his case of Charcot's disease.

Dr. David M. Bosworth, New York, N. Y.: When similar operations—such as the femoro-ischial transplant or the Brittain operation—are first introduced, it would seem that one or the other would supplant its alternate in usefulness. As time goes on, however, one may find different indications of usefulness for each procedure. Neither of them supplants routine hip fusion, where the bony parts of a hip joint remain relatively intact and in position and where mixed infections are not present. The percentage of absolute ankyloses reported by each procedure to date is about equal. For a femoro-ischial transplant to work well, considerable shortening and displacement upward of the trochanteric portion of the shaft must have occurred. Under such circumstances, gain in length can be secured by transplantation to the ischium under tension, by using a grooved pry. In such situations the Brittain operation not only fails to gain length, but actually allows for shortening. The upper end of the femur slides inward and upward under the oblique lower margin of the tibial graft, which has been inserted, through the osteotomy site, into the pelvis. In cases where only moderate crumbling of the head of the femur and slight upward displacement are present, there is so much relaxation after a femoro-ischial transplant that instability results. In such cases the Brittain operation is excellent. Even here, however, it is excellent only if so much disorganization has occurred that routine hip fusion cannot be done.

Where a mixed infection is present in the hip joint, one should not expect that surgical exposure by either the Brittain operation or the femoro-ischial transplant will remain outside the infected area. We have shown that, normally, extension of the synovial membrane of the hip joint downward to the level of the lesser tuberosity of the femur occurs. The placing of a graft or the cutting off of the femoral shaft at this level, therefore, may traverse infected tissue. I believe that this accounts for the disorganization of some of the Brittain grafts, and for the occasional flare-up of infectious lesions by femoro-ischial transplants. There is always the great advantage in a femoro-ischial transplant that additional separate dead bone fragments need not be implanted, and that a second ostectomy site need not be created. As regards this latter, our records have led us to expect, in approximately 10 per cent. of the cases, pathological fracture of the tibia following ostectomy in securing grafts.

To crystallize our feeling, therefore, we would judge that hip fusion should be done whenever possible; that the Brittain operation might prove preferable where only moderate disorganization of the femoral head and neck were present and but little upward displacement of the trochanteric area existed; and that the femoro-ischial transplant would be the method of choice where massive destruction of the head and neck of the femur had occurred and marked upward displacement of the trochanteric portion beyond the acetabulum was present.

SYMPATHETIC BLOCK OF THE STELLATE GANGLION

Its Application in Orthopaedic Conditions *

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Sympathetic block, a development of the observation that areas made anaesthetic through local injection show increased surface temperature, has become a most important branch of regional anaesthesia. A plausible explanation for this effect has been suggested by Ochsner and DeBakey: "As a result of vasospasm there occurs increased filtration pressure, anoxia of the capillary endothelium, and diminution in the flow of lymph, setting up a vicious circle. Interruption of the vasoconstrictor impulses by procaine hydrochloride block of the regional sympathetics breaks this vicious circle by increasing pulsations, improving circulation and tissue oxygenation, and increasing lymph flow." The diagnostic, prognostic, and therapeutic applications of sympathetic block to the lower extremity are well known and have been employed frequently. In contrast, regional block of the sympathetic nerves supplying the upper extremity has been neglected. Stellate block is not only equally applicable to similar conditions of the upper extremity, but to many other painful conditions as well.

The authors have employed infiltration of the stellate ganglion with procaine hydrochloride in approximately 400 cases of painful orthopaedic lesions in the upper extremities, from which they have selected for presentation eighteen cases of acute subdeltoid bursitis; twelve cases of periarthritis; five cases of myositis and fibrositis; eight cases of hypertrophic arthritis; five cases of the infectious arthritides; twenty-five cases of pain and swelling following trauma (fractures, dislocations, and contusions); and five cases of causalgia following trauma (Table I). In each category, only those cases have been chosen which have been followed carefully.

1. *Acute Subdeltoid Bursitis*

Acute subdeltoid bursitis is characterized by pain, swelling, heat, redness, and tenderness, localized over the bursa; and by limitation of shoulder motion because of pain. Eighteen patients with this condition were treated by stellate block. The patients ranged in age from nineteen to seventy-eight years; the average age was 42.6 years. Five of the patients were women. The average duration of symptoms was 5.8 days. Most of the patients had been treated previously by the application of heat, massage, or immobilization, or by a combination of two or more of these measures; only four patients had had no previous treatment. Immediate relief was classified as excellent in 83.3 per cent. and as good in 16.7 per cent. of the cases. Fifty per cent. of the patients obtained considerable relief from pain after one block; the remainder required additional blocks at intervals of from one to seven days; but in all the pain was relieved subsequently. Striking improvement in motion in the joint was noted in all cases, and this usually developed within a few minutes after a successful block.

2. *Periarthritis*

This condition is a sequel of acute bursitis, in which adhesions form in and about the bursa and involve the periarticular structures. Motion is limited, because of the pain and adhesions. Although symptoms are usually of longer duration, they are not so severe as in

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 21, 1946.

TABLE I

PAINFUL ORTHOPAEDIC LESIONS IN SEVENTY-EIGHT PATIENTS TREATED BY STELLATE BLOCK

Diagnosis	Number of Cases	Average Age (*Years*)	Average Number of Blocks	Results						
				Immediate			Remote			
				Good (*Per cent.*)	Fair (*Per cent.*)	Poor (*Per cent.*)	Good (*Per cent.*)	Fair (*Per cent.*)	Poor (*Per cent.*)	Not Followed
Acute subdeltoid bursitis	18	42.6	1.8	100			77.7	16.6		5.5
Periarthritis	12	56.7	2	100			50.0	41.7	8.3	
Myositis and fibrositis	5			100			80.0	20.0		
Hypertrophic arthritis	8			100				50.0	37.5	12.5
Infectious arthritides	5			80	20		40.0		60.0	
Posttraumatic pain and swelling	25		1.7	100						
Posttraumatic causalgia	5			80		20				

the group with acute inflammation. After subsidence of the pain, these patients were treated routinely by the application of heat, light massage, and relaxed circumduction. In this series of twelve cases of periarthritis, the ages ranged from thirty-six years to seventy-nine years, with an average age of 56.7 years. Symptoms lasted an average of 32.6 days. Half of the patients in this group were women. The average number of blocks required for relief was two, at intervals of from one to seven days. The end results in this group were not so striking as those in the patients with acute subdeltoid bursitis, but this was to be expected in view of the structural changes which occur in such cases. However, pain was relieved sufficiently to make possible a much more active range for the institution of physical therapy.

3. *Myositis and Fibrositis*

These conditions are characterized by diffuse involvement of a group of muscles; the involvement may be acute or chronic. The patient often gives a history of previous muscle strain or of unusual exposure. The condition is analogous to the more widely known lumbar myofascitis.

Since there were only five cases in this group, statistical analysis is not possible. It was noted, however, that eventual relief was secured over a longer period of time; this observation tends to minimize the role played by the blocks. The relief obtained was probably due to anaesthetization of the communicating branches to the fifth and sixth cervical nerves from the middle cervical ganglion.

4. *Hypertrophic Arthritis*

This is a painful inflammation of the elbow, shoulder, or hand, following formation of new bone at the articular margins and degeneration of the articular cartilage. It is usually seen in middle-aged persons who also show involvement of other joints. The ages in this group ranged from forty-three years to seventy-nine years. Six of the eight patients were women. The duration of symptoms varied from three weeks to two years. Most of the patients had previously been treated with salicylates and the application of heat. More

than one block was required in all but one case. Relief from pain was transitory, and this was apparently due to the irreversible tissue changes which had already occurred.

5. *Infectious Arthritides,—Specific and Non-Specific, Acute and Chronic*

Five men, ranging in age from seventeen to forty-nine years, with infectious arthritis of from five weeks' to three years' duration, had between one and three blocks at intervals of from one to seven days. Only temporary relief from pain was obtained. Repeated blocks, by making the condition more tolerable, might also make it more amenable to specific treatment.

6. *Pain and Swelling Following Trauma (Fractures and Dislocations)*

Seventeen patients with pain and swelling following fractures or dislocations were included in this group. Stellate block was done after reduction of the fractures and dislocations; the relief of pain and diminution in swelling were so pronounced in the majority of cases that the authors now use this procedure almost routinely for patients complaining of pain and "tight casts". In this group, the ages varied from fifteen to seventy-four years. Seven of the seventeen patients were men. The series included cases of anterior dislocation of the shoulder, fracture of the spine of the scapula, fracture of the surgical neck, fractures of the upper and middle thirds of the humerus, Colles's fracture, fractures of the fingers, and supracondylar fractures of the humerus. The number of blocks averaged 1.94, at intervals of from one to seven days. The immediate result was excellent, and in many cases it was possible to avoid cutting casts which formerly would have required splitting.

7. *Pain and Swelling Following Trauma (Contusions)*

In this group of eight cases of pain and swelling following contusions, relief of pain was almost immediate,—presumably because of the relief of vasospasm secondary to the direct trauma. The ages ranged from twelve to fifty-two years, with an average of 32.5 years. Two of the eight patients were men. When these patients were seen after an interval of one week, their pain had uniformly subsided; this may have been due to the natural resolution of the process, but apparently the blocks also hastened it.

Mahorner used sympathetic blocks in a number of conditions for residual posttraumatic pains and for causalgia, and commented upon the remarkable relief from pain in at least 75 per cent. of the cases. In many of these cases pain was "the only residual which would interfere with an otherwise satisfactory or perfect result".

8. *Posttraumatic Causalgia and "Phantom" Pain After Amputation*

In these five cases there was definite injury to the nerves. All but one of the patients were men; their ages ranged from twenty-six to fifty-four years. The cases included traumatic amputation of two fingers, dislocation of the left shoulder and paralysis of the deltoid muscle, traumatic amputation of the right hand, compound shotgun fracture of the right elbow, and compound fracture of the left elbow.

Again it was found that blocks, as a rule, gave excellent relief from pain and diminution of swelling. One patient in this group suffered from intolerable causalgia after a crushing injury to his hand. Complete and immediate, but transient, relief followed blocking; and this was carried out twice a week for six months (a total of fifty blocks) before the patient decided to have a ganglionectomy. We have not had the opportunity to try blocks for "phantom" pain following amputation of the upper extremity, but the procedure proved of definite value in two cases of mid-thigh amputation. Leriche and Fontaine relieved neuralgia of the amputation stump by this method. Livingston reported ten cases of amputation of the upper extremity with classical "phantom" pain. All of these patients had one or more injections of procaine hydrochloride near the thoracic sympathetic ganglia of the affected side. "In 8 of the cases the patient felt immediate relief from pain, together with an extraordinary sequence of subjective and objective changes."

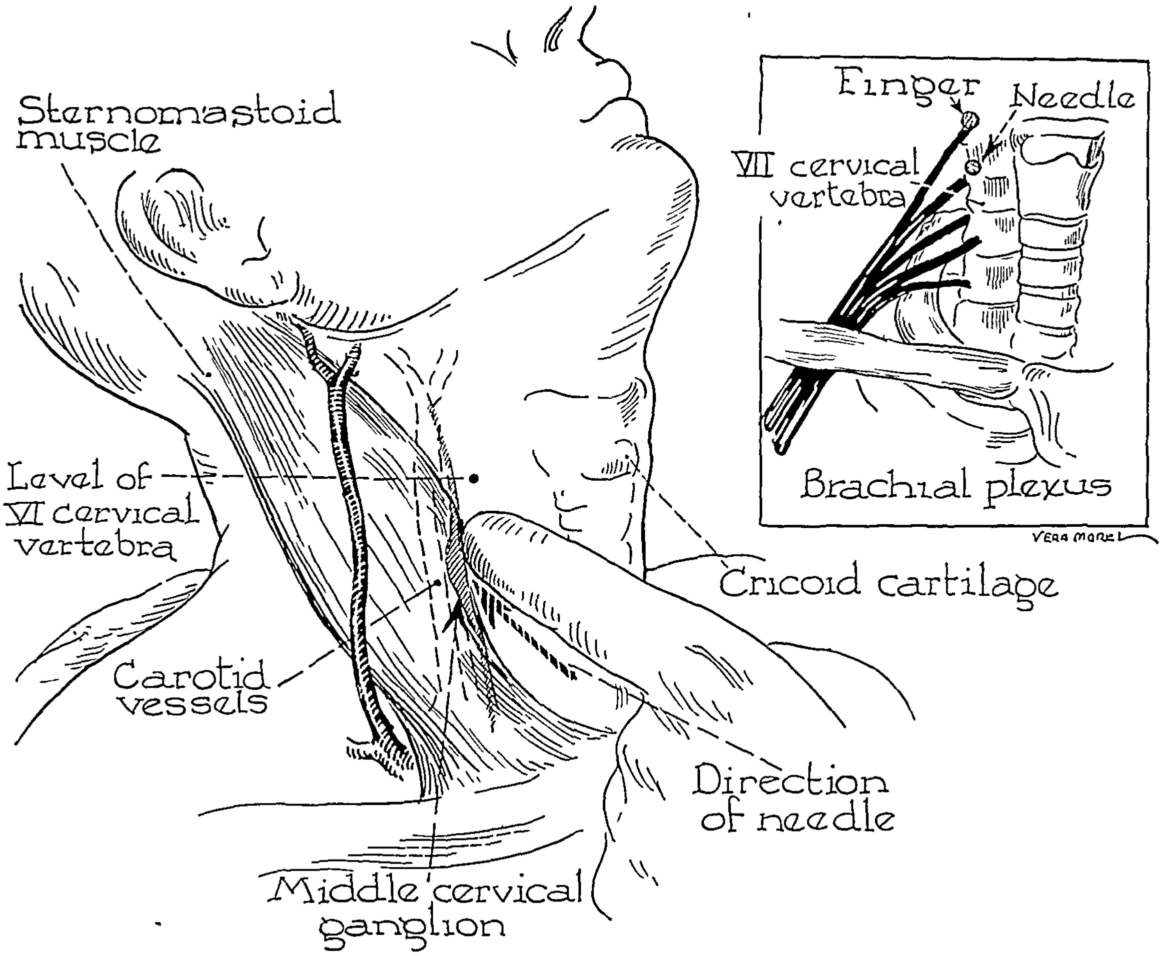

FIG. 1-A

In Technique I, the patient is supine, with the head rotated to the opposite side to make the sternocleidomastoideus stand out. The sixth cervical vertebra is located in relation to the seventh cervical spinal process posteriorly, and to the cricoid cartilage anteriorly. The finger, inserted toward the sixth cervical transverse process, displaces sternocleidomastoideus and carotid-sheath structures laterally, and trachea medially. The finger is pushed in until it touches the sixth cervical transverse process or the region of origin of the scalenus anterior, and is held there. The needle is inserted directly below and parallel to the finger, until it touches or approximates the transverse process.

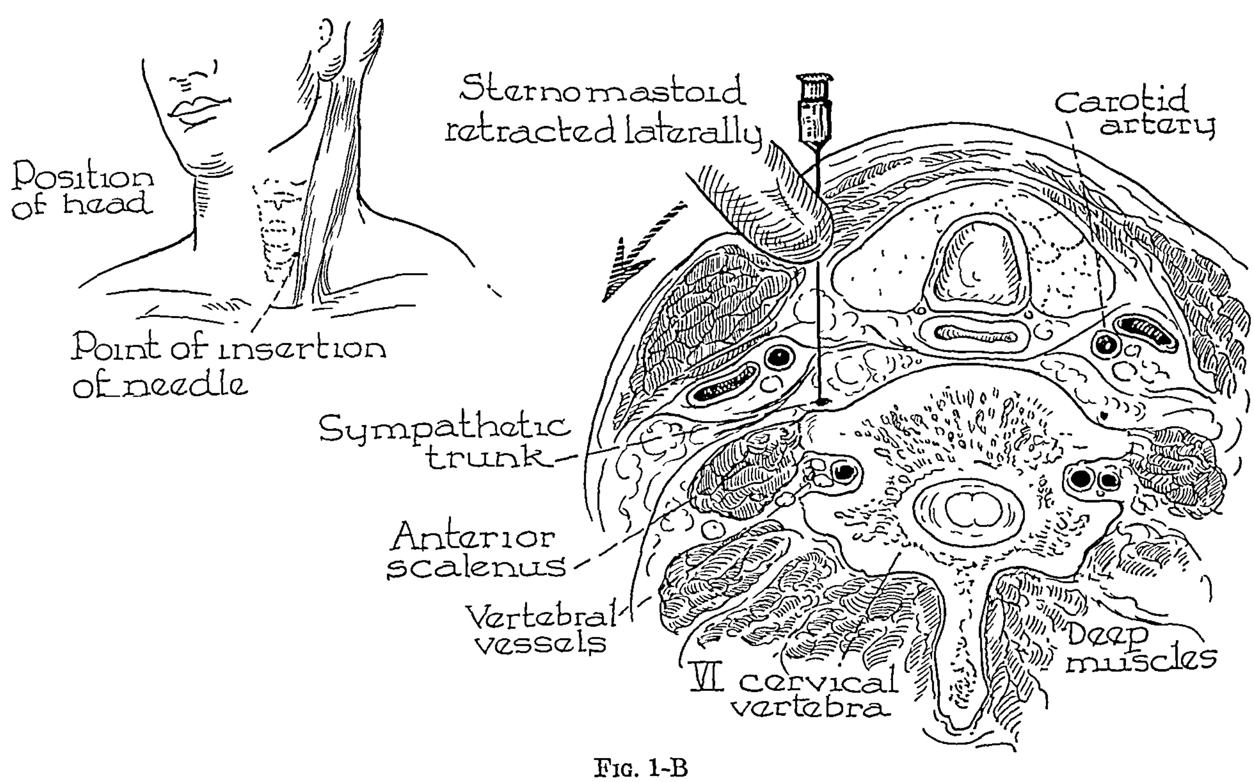

FIG. 1-B

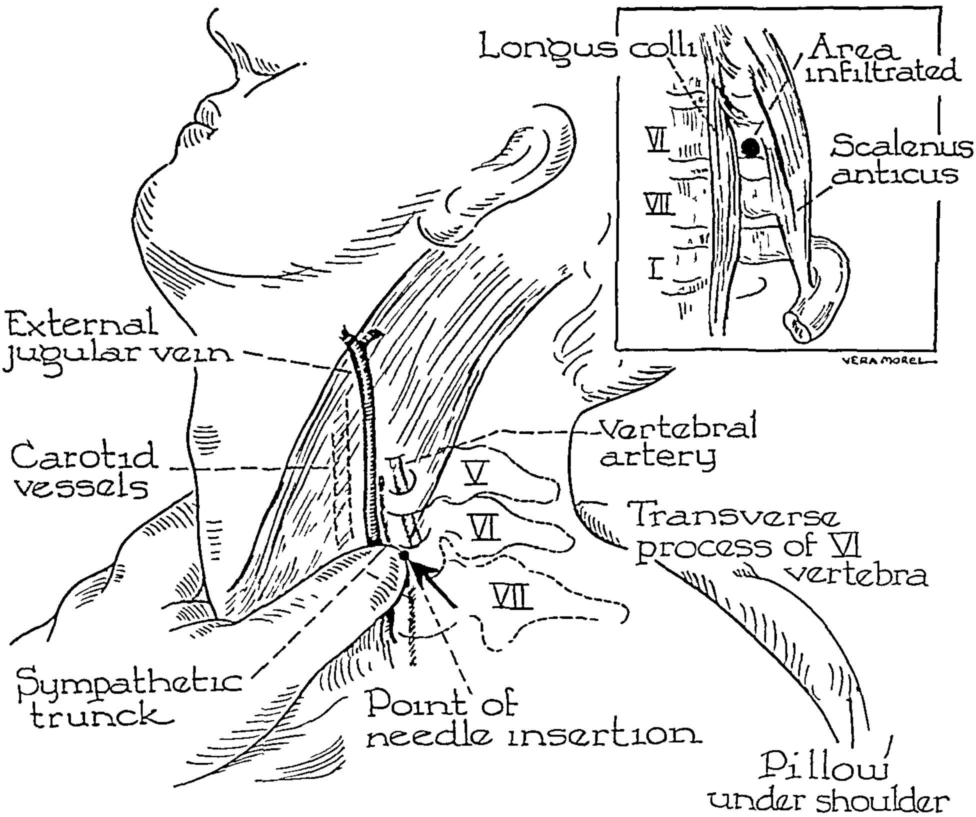

FIG. 2-A

In Technique II, the patient is supine The head is turned up and away from the side to be blocked, in order to make the sternocleidomastoideus stand out The sixth cervical transverse process is located as before *(See Figs 1-A and 1-B) The sternocleidomastoideus and external jugular vein are* displaced anteriorly and the needle is inserted at right angles to tip of thumb, which is held on posterior margin of sternocleidomastoideus, anterior to the sixth cervical transverse process

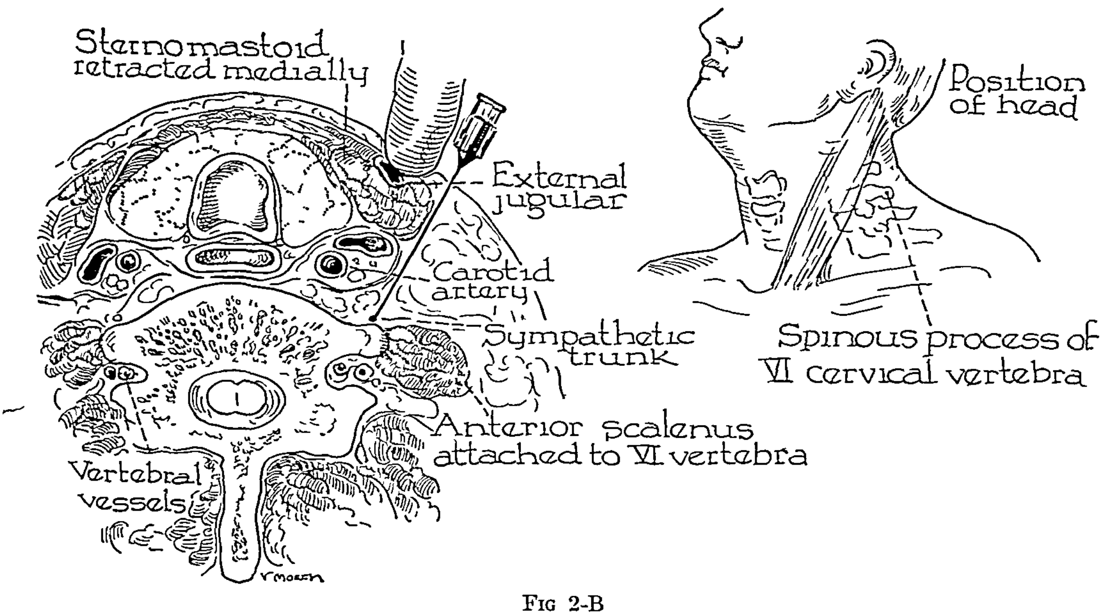

FIG 2-B

DISCUSSION

The results obtained from stellate block in these cases indicate that the procedure is of definite therapeutic value in certain orthopaedic conditions. The infrequency of its use

can be attributed to lack of a routinely successful approach; fear of vascular, neural, or pulmonary complications; and uncertainty as to its indications. As in other surgical procedures, careful study of the anatomy and landmarks involved, an understanding of the technique, and an awareness of possible complications will greatly reduce the risk.

PROCEDURE

The authors have tried all the approaches that they could find described in the literature and have obtained the most consistently satisfactory results from modifications of the descending-infiltration technique of de Sousa Pereira. In an excellent paper, he describes the well-known anatomical features; and also points out the importance of the aponeurosis at the base of the neck, which acts as a pathway of diffusion for the anaesthetic solution from the level of the transverse process of the sixth cervical vertebra to the middle cervical and stellate ganglia. By utilizing this pathway, one can obtain consistently good blocks with needles of Wassermann or hypodermic length, instead of the usual and more lethal spinal-length needle. These "short-needle" techniques have enabled the authors to do stellate blocks with greater safety, ease, and speed than is possible with any of the other methods.

Technique I (Figs. 1-A and 1-B): The patient is given one of the shorter-acting barbiturates thirty minutes prior to infiltration. With the patient supine and the head flexed slightly on a pillow and rotated away from the site of injection, the manipulating finger is placed approximately one and one-half inches above the sternoclavicular junction. Pressure is exerted toward the transverse process of the sixth cervical vertebra, which is easily located in relation to the prominent seventh cervical spinous process and to the cricoid cartilage, anteriorly. Forcible displacement of the sternocleidomastoideus and carotid-sheath structures laterally, and of the trachea and oesophagus medially, is produced. With further inward pressure, the medial border of the scalenus anterior muscle can be felt. The finger tip is held at this point, in relative contact with the transverse process of the sixth cervical vertebra, which is palpable in some cases. After a skin wheal has been raised, a 22-gauge or 24-gauge needle, one and one-half to two inches long, is inserted below and parallel to the palpating finger, until its point either touches or approximates the lower border of the transverse process. The syringe is then removed from the needle, and the fluid in the hub is watched while the patient inspires deeply. If the needle is within the pleural space, fluid will be sucked in. Fluid will well out if the subarachnoid space has been tapped. The syringe is reinserted and, if no blood is obtained on aspiration, one cubic centimeter of 2 per cent. procaine hydrochloride is injected slowly. If no untoward reaction occurs, an additional four cubic centimeters is injected after aspiration; the needle is removed; and the patient is helped to a sitting position. If a good block has been obtained, conjunctival injection appears almost immediately and precedes the miosis, ptosis, exophthalmos, and anhidrosis typical of Horner's syndrome. If vasomotor block and pain block of the upper extremity do not appear within fifteen or twenty minutes, even though Horner's syndrome has developed, it is probable that diffusion of the anaesthetic has been insufficient for complete block of the stellate ganglion. De Sousa Pereira advises that, when this occurs, reinfiltration be performed inferiorly, toward the base of the seventh cervical transverse process.

Technique II (Figs. 2-A and 2-B): Another approach, which is employed by Patzer, is easier to perform, particularly in thin persons. With the patient supine, the transverse process of the sixth cervical vertebra is palpated posterior to the external jugular vein and behind the posterior border of the sternocleidomastoideus. The palpating finger then displaces the sternocleidomastoideus and the carotid sheath medially; and infiltration is effected, as before, anterior to the transverse process of the sixth cervical vertebra and medial to the border of the scalenus anterior.

COMPLICATIONS OF STELLATE BLOCK

Several possible complications may follow stellate block of the sympathetic ganglia f the upper extremities.

Psychic reactions are manifested by mild, transient signs of syncope, palpitation, perpiration, weakness, and excitement; they can be controlled by assurance and sedation.

Procaine reaction—fortunately, a rare occurrence—is evidenced by excitement, palpiation, and dyspnoea, followed by convulsions and respiratory failure, and terminating ossibly in death. Such a serious development can usually be prevented by close observaion after the initial small injection. If this reaction occurs, the patient should be given arbiturates intravenously, and oxygen should be administered. A prophylactic skin test s advisable as a routine procedure.

Pneumothorax occurred in one case after a block by the "long-needle" technique. Dyspnoea and thoracic pain were slight, and subsided completely after twenty-four hours of treatment by bed rest and the administration of nasal oxygen.

Hematomata following perforation of an artery or vein occurred in six cases, but were of no consequence, except that they precluded the injection of procaine.

Subarachnoid injection is a fatal complication, but one which is absolutely avoidable.

Recurrent laryngeal paralysis and *phrenic block* are manifested by transient hoarseness, aphonia, and unilateral paralysis of the diaphragm. The symptoms recede spontaneously. Obviously, bilateral block of the stellate ganglion should never be contemplated.

CONCLUSIONS

In cases of recent acute lesions of the upper extremity, stellate block affords relief from pain which is almost universally gratifying. These patients submit to, or even seek out, consecutive blocks. That the pain is probably vasospastic in origin is suggested by the fact that complete relief follows one or more blocks at frequent intervals. Clinical substantiation is evidenced by the results obtained in acute inflammatory and posttraumatic conditions, in which the major etiological factor is known to be circulatory impairment.

In chronic cases, in which the lesions have been present until such anatomical changes as adhesions, erosion of cartilage, or aberrant calcification supervened, it is obvious that only transitory relief from pain can be obtained. Adjunctive physical therapy should be employed in such cases. The range of physical therapy tolerated is in direct proportion to the relief of pain afforded by stellate block; and, in cases showing definite but transient improvement, it may be well to consider blocking with more noxious chemicals, such as alcohol derivatives; or even employing sympathectomy.

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DISCUSSION

Dr. J. E. M. Thomson, Lincoln, Nebraska: It is unfortunate that novocaine block of the sympathetics is not more generally recognized as a diagnostic and therapeutic aid in connection with those con-

ditions in which local circulatory insufficiency can be influenced by breaking the reflex arc. However, it must not be considered a panacea. The work of Ochsner and DeBakey and of others stimulated my experimental studies in this direction some years ago. These studies opened my eyes to the opportunities afforded for the therapeutic use of novocaine block in many conditions where I had previously not recognized its value.

This essay eminently calls attention to many of these conditions. My experience has been far more limited as to number of cases treated, but the gratifying observations with respect to block of the stellate ganglion in subdeltoid bursitis, posttraumatic swelling of the upper extremity, and certain subacute infectious or traumatic soft-tissue derangements of the elbow would lead me to be convinced of the authors' results in the other conditions enumerated.

It is well that attention has been called to the pitfalls of inexperience in the technique of performing the block; but, if one follows meticulously either the technique described by Ochsner and DeBakey or that of de Sousa Pereira, there is relatively little danger of complicating phenomena.

Our experimental work in animals showed that block of the stellate ganglion gave its maximum response for an average of fifty-six hours; and, with this as a criterion, we have observed that this maximum of effectiveness, as checked by thermocouple in the human, averaged about seventy-two hours. Therefore, we have the feeling that it is better to repeat the block after seventy-two hours than to chance having the pain and symptoms return to the region involved; for, if maximum effectiveness of the block can be maintained over a longer period, the possibilities of permanent relief are more probable.

Dr. Edward L. Compere, Chicago, Illinois: For about six years, I have been using a method similar to that described by Dr. Caldwell, Dr. Broderick, and Dr. Rose for injecting the muscles and the sympathetic ganglia of the neck. My experience does not include so many cases as have been reported by these authors. I have not had the opportunity of treating a case of phantom-limb pain. In most of my patients, some type of physiotherapy has been employed, in addition to the injections of procaine. The results which I have obtained have been approximately as satisfactory as those reported by these authors.

I do wish to raise one question. The immediate improvement in the circulation of an upper extremity and the relief of pain may be due to relaxation of a tight scalenus anterior muscle, into which some of the procaine has been injected. I have also observed beneficial results in my patients when there was evidence that the stellate ganglion had not been reached, as shown by complete absence of Horner's syndrome. The scalenus anterior syndrome is merely a reflex spasm of the muscle produced by any one of several conditions in the area of the cervical spine. Therefore, I am of the opinion that an effort should be made to relax this muscle by injecting a few cubic centimeters of the procaine into the muscle, as well as into the fascial spaces at the level of the transverse processes of the sixth cervical vertebral body, whence it may infiltrate downward to the stellate ganglion.

I have found it much easier to carry out the procedure of procaine injection with my patient sitting upright. On several occasions these patients have become quite faint, and it is most important that an assistant be ready to lend a hand, should syncope impend.

THE USE OF ILIAC BONE IN BONE-GRAFTING AND ARTHRODESIS

BY CAPTAIN C. A. LUCKEY AND LIEUTENANT COLONEL CARROLL O. ADAMS

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In reconstructive work on war casualties, early surgical intervention is the treatment of choice in many cases of defective bone union. Many surgeons believe that, even if union is minimum, it will eventually be sufficient to withstand the stress and strain put upon it. This is frequently not the case. In war injuries a large portion of the bone may be lost, and union across a small bridge on one side of the fracture will never be sufficient. Therefore, early intervention is frequently to be preferred.

TREATMENT OF INJURIES

The types of non-union resulting from war injuries differ in several respects from those resulting from civilian injuries.

1. The patient may not have had the most desirable early treatment, due to circumstances. Thus the problem of infection must be dealt with in many cases.
2. Since most war wounds are not closed primarily, subsequent rapid closure of the wound, to prevent fibrosis and resulting joint limitation, is attempted.
3. In many instances the healed wounds must be repaired so that there is adequate soft tissue, before bone-grafting can be undertaken.
4. The non-union must be overcome. Tendon and nerve injuries, which are common complications of war wounds, must be repaired as early as possible; but frequently such repair must be delayed until after the soft tissue has been revised or even after the bone has been grafted.

Indications for Bone-Grafting

Bone grafts are indicated in the following conditions:

1. Where there is a loss of continuity, due to fractures that have not healed properly, and where there is resulting disability. If there is no disability, as in some cases of non-union of the clavicle, carpal navicular, and fibula, no treatment may be indicated, and bone-grafting should not be done. In rare instances in other bones, non-union causes few symptoms or none at all, and surgical treatment should not be advised.
2. Where there is minimum bony union, and the prognosis is for many months of disability while waiting for functional strength to return to the bone. Many of the bones have repeated fractures during this convalescent period.
3. In some fresh fractures where complications and delayed union are anticipated. The use of cortical tibial bone or a large piece of iliac bone, applied with screws, might hasten healing and serve as a form of internal fixation, instead of a plate.
4. In some cases in which an osteotomy is done to correct angulation that is causing functional disability. The bone graft is applied to make rapid bony union more certain, and to serve as internal fixation during the early convalescence.
5. To assist in arthrodesis in some cases.

Relation of Infection to Bone-Grafting

Formerly, six months was considered the minimum period which should elapse between the cessation of drainage and the institution of bone-grafting, but this was not considered adequate if there had been prolonged drainage. Three months is now considered an adequate waiting period after the cessation of drainage in many cases, for the following reasons:

1. Infections are cleared up much faster now by the use of repeated surgical attacks on wounds for the removal of sequestra and foreign material.

2. Wounds are closed more rapidly by the use of secondary closures, skin grafts, and the like.

3. The procedures mentioned and early bone-grafting are made possible by the use of the sulfonamides and penicillin, particularly penicillin.

Even though no sequestra have been visualized by roentgenogram, it is important to do a surgical exploration of the draining wound, especially if the drainage is not subsiding at a satisfactory rate. Not infrequently foreign bodies which are not radiopaque, such as bits of clothing, may be present in the wound and incite a persistent thick, purulent, foul, yellow discharge. This discharge should arouse suspicion concerning the presence of bits of clothing in the wound.

The minimum time between subsidence of infection and surgery is two months for skin work and three months for bone. The periods should be increased if prolonged drainage followed the initial injury. These periods are safe only if penicillin or the sulfonamides have been used before and after operation.

Early Closure of Wound

After deep drainage has ceased, the wound will heal rapidly by proliferation of granulation tissue. However, some of the extensive wounds can be closed more rapidly by applying a split-thickness skin graft to the granulating area. Saline dressings, changed every four hours, rid the wound of superficial infection in a few days and prepare the granulating bed for the skin graft. These grafts may not be completely successful in all cases; nevertheless, there is enough "take" to more than justify the procedure.

By getting the wound healed in this manner, one can speed up the date of bone-grafting, since this is calculated from the time the wound has healed. In addition, scar-tissue formation is diminished, which, in turn, means less joint limitation.

Adequate Soft-Tissue Coverage

Elimination of the more extensive soft-tissue defects is necessary before any bone reconstruction can be undertaken. Obviously, the smaller defects can be excised, and the skin edges can be undermined and approximated without undue tension. If the defect is slightly more extensive, a releasing incision, with shift of a ribbon flap to the opposite skin margin, will produce adequate closure. The defect produced by shifting the flaps is then covered with a split-skin graft. Normal skin, with its subcutaneous fat, now covers the area through which the surgical incision will eventually be made. Direct flaps from the abdomen provide excellent skin for the arm and hand. In the lower extremity, one can transfer a pedicle from one leg to the other. These pedicle grafts may be transferred either directly or by the delayed method. The method used is determined by the length of the pedicle and the appearance of the flap as it is elevated gradually. Direct flaps can also be transferred from one thigh to the opposite leg. Usually the pedicle of the graft is detached three weeks from the time the graft is done.

If the defect is quite extensive, a tubed pedicle graft may be necessary. The authors have done all types of soft-tissue coverage not necessitating the making of a tube. In Army practice, tube grafts have been done at Plastic-Surgery Centers. The value of complete coverage of all the open areas at the time the pedicle graft is done needs special stress. Reference is made especially to the donor site of the pedicle graft and also to that part of the underside of the pedicle which does not come into contact with the recipient area. If the denuded areas are not covered with a split-skin graft, infection and fibrosis result. Frequent dressings are then necessary and the bone surgery must be delayed. When split-thickness grafts are used to cover the donor site of the pedicle, a completely closed and surgically clean wound is the result.

In non-union due to an old compound fracture, many bacteria undoubtedly are im-

bedded in the overlying scar tissue. While imbedded in the scar, they are dormant. When the scar is incised surgically, infection may result from activation of the dormant bacteria. This accounts for some of the flare-ups of infection after operation. In many instances the scar should be excised a few weeks before bone-grafting, so as to avoid this complication. Even though the scar does not appear troublesome, excision prior to bone-grafting may avoid a flare-up of infection.

At the time of scar excision, one must anticipate the incision to be made during bone-grafting. By planning ahead, one can sometimes avoid placing the incision directly over superficial bone and putting the skin under undue tension.

PHYSIOLOGY OF BONE TRANSPLANTS

There is rarely non-union in spongy bones such as the ilium, the bodies of the vertebrae, and the small bones of the hands and feet. The only exception is in certain bones of the body where part of the bone may become non-viable, due to interruption of its blood supply by trauma. Cancellous bone having thin trabeculae, extensive contact with tissue fluid, and an extensive blood supply is rapidly replaced when used as a transplant; therefore bony union is rapid.

Cortical bone is very specialized. Its density delays the firm adherence of callus. The vascularity of the cortex is minimum; so the new bone callus at the fracture site must be produced and nourished by an ingrowth of new vessels, sometimes from a considerable distance.

Phemister [16,19] has observed the changes which bone undergoes when transplanted. He states that, with the exception of a few cells on the surface, the greater mass of cells die. Subsequent changes in the graft then depend upon its location: If it is in a useful position, progressive changes take place; if in a useless location, retrogressive changes occur. Callus then forms at either end to help unite the transplant to the fragments. Creeping substitution of the dead cortex gradually occurs by the ingrowth of capillaries, with dilation of the haversian canals, absorption of the old bone, and deposition of new bone in its place. The dead bone is absorbed by mononuclear and occasional polymorphonuclear osteoclasts. New bone is then deposited on parts of the walls of the dilated canals in successive layers. Once the graft has become fixed at both ends, the tissue between the fragment ends no longer remains static; but it responds to functional stress and strain and ossification occurs. Likewise the graft will become hypertrophied, depending upon the force transmitted through it.

After strength has increased so that it satisfies the demands of function, remodeling of the bone takes place. Eventually a new medullary cavity is formed, and the excess bone around the old site of non-union is absorbed, until the final contour is not unlike the original [17,20].

BONE USED IN GRAFTING

Local Bone

Bone taken from the region of the fracture may be used as a sliding type of inlay graft. It may also be cut into small chips and laid back into the slot from which it was removed.

Multiple drilling with a small drill is one form of local graft, for it produces many small particles of bone at the fracture site, in addition to opening up new channels for the invasion of this area by new blood vessels.

Tibial Bone

Several forms of graft can be obtained from the tibia. From the mid-shaft, dense, heavy cortical bone can be obtained. From the upper part, bone can be obtained which has a thin cortical layer and considerable underlying spongy bone.

Fibular Bone

The fibula can be split and used for onlay grafts, or it can be left whole and used as a "dowel". Removal of the upper or middle portion of the fibula causes the patient no disability.

Bone from Ribs

Rib material offers a readily available source of bone for grafting. In grafting long bones, it has no advantage over iliac bone. It has been used to advantage in doing spinal fusions on cases of scoliosis with marked deformity of the rib cage [5]. It has also been used in grafts of the mandible. The authors have had no experience with rib grafts.

Iliac Bone

In recent years the use of cancellous bone has been emphasized by numerous workers. Ghormley has stressed the value of cancellous bone removed from the region of the posterior superior spine of the ilium, in performing lumbosacral fusions. Abbott and his co-workers have stressed the wide use to which iliac bone may be put in bone-graft surgery. Mowlem used cancellous bone chips to bridge large gaps in the long bones, where there was loss of bone substance and no bony contact whatsoever between the fragments. He stated that cancellous bone was being used almost to the exclusion of cortical bone.

The advantages of cancellous bone over cortical bone have been stressed repeatedly in the past. The chief advantage is that union and replacement are more rapid, due to the porous nature of the bone. Secondly, strips of iliac bone can be placed across the site of non-union with a minimum amount of dissection and stripping of periosteum. In addition, there is no fear of injury to the donor site, as there is when the tibia is the donor. Usually bone from the anterior part of the wing of the ilium can be used. In those cases where the patient is placed prone upon the operating table, however, the posterior portion of the ilium is utilized.

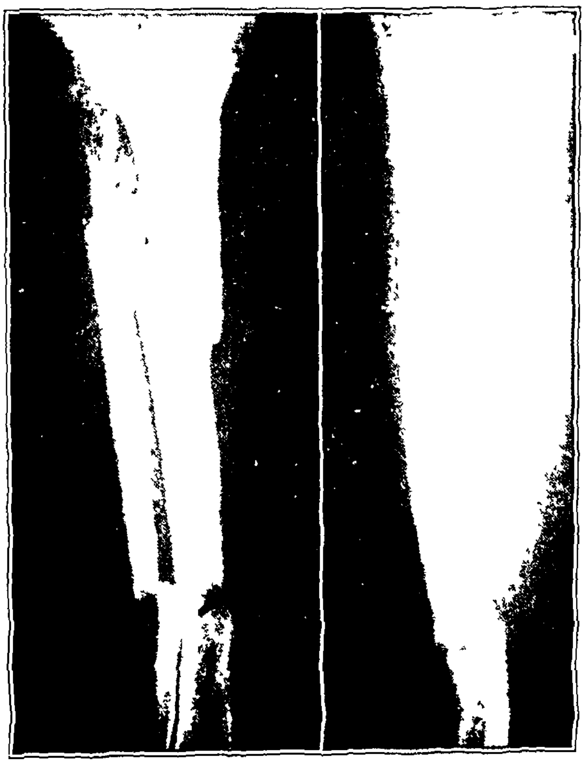


Fig. 1-A

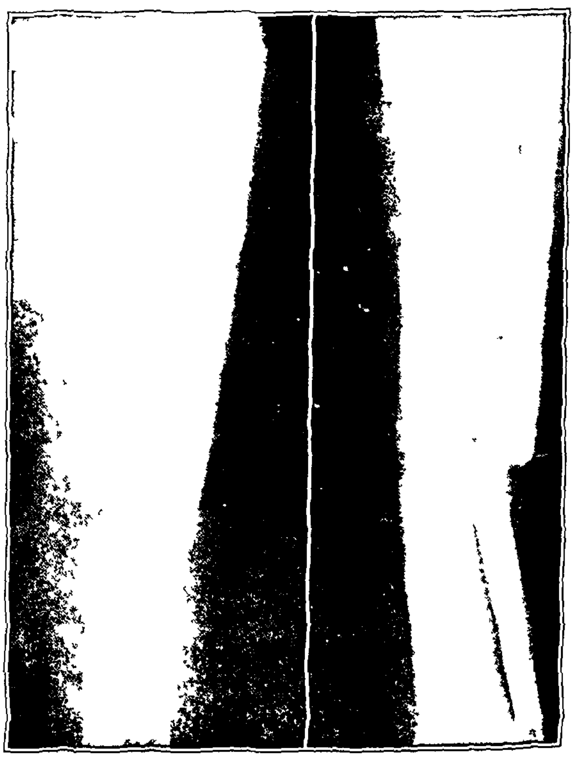


Fig. 1-B

Fig. 1-A: Before operation.

Fig. 1-B: After operation. Non-union of tibia treated by removing bone across fracture site, cutting graft into small chips, and reinserting the chips in the slot. Replacement of bone is rapid, since there is no large transplant, but rather multiple small chips. (*Letterman General Hospital Photographic Laboratory.*)

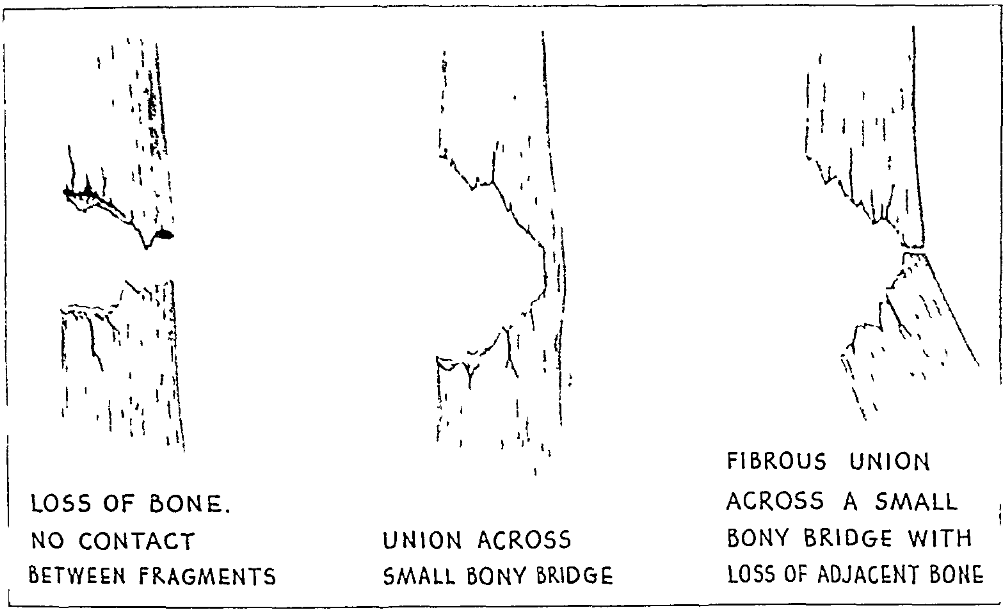


Fig. 2
Types of non-union encountered.

OPERATIVE TECHNIQUE

The type of graft used and the method of fixation vary with the nature of the non-union and with the bone involved. When reduction is difficult to maintain, the authors employ the massive onlay graft described by Henderson. Sliding grafts [11] and inlay grafts [3] have been employed in isolated instances. Usually the onlay graft is preferable to the inlay type. In cases suitable for a sliding graft, the choice has sometimes been to remove the graft, cut it up into chips, and replace it along the groove from which it was removed (Figs. 1-A and 1-B).

Bone drilling was not employed by the authors. Those cases suitable for drilling are

Fig. 3-A

Fig. 3-B

Fig. 3-A: Before operation.
Fig 3-B: After operation. Defect corrected by insertion of multiple iliac strips.

FIG. 4-A

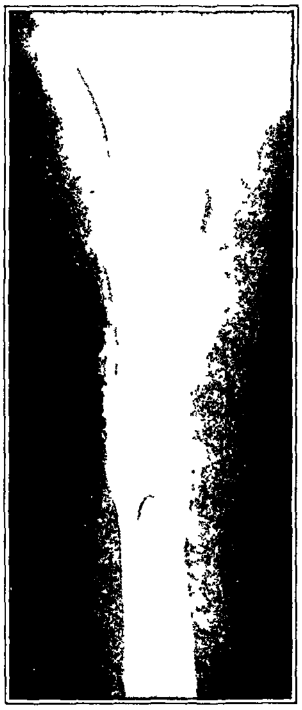


FIG. 4-B

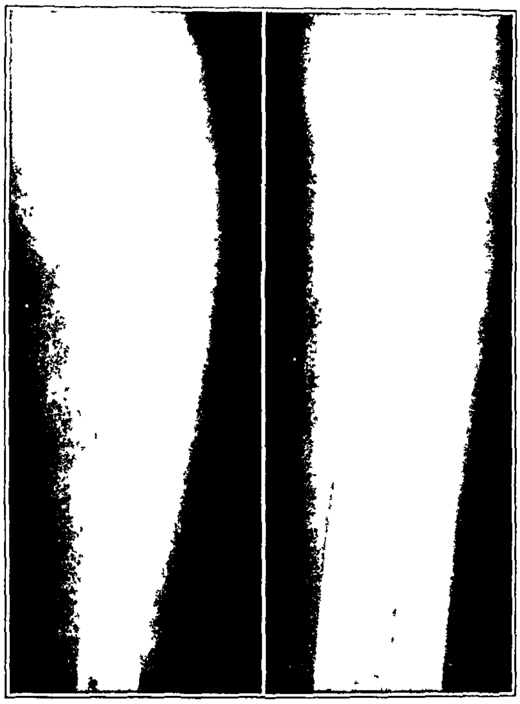


FIG. 5

Fig. 4-A: Before operation.

Fig. 4-B: After operation. Humerus, with motion at site of non-union, treated by inserting multiple iliac strips. No internal fixation was used; position was maintained by plaster cast. Occasionally cast must be wedged to correct angulation. (*Letterman General Hospital Photographic Laboratory.*)

Fig. 5: Two-inch defect in ulna has been grafted with iliac bone. (*Letterman General Hospital Photographic Laboratory.*)

also suitable for iliac grafts or chip grafts, and the latter methods are more certain of bringing about bony union.

Osteoperiosteal grafts are rarely used except in an occasional joint arthrodesis, as described by Delangenière and Lewin. Iliac grafts have been more suitable. Intramedullary bone was used, as a rule, only in metacarpal grafts.

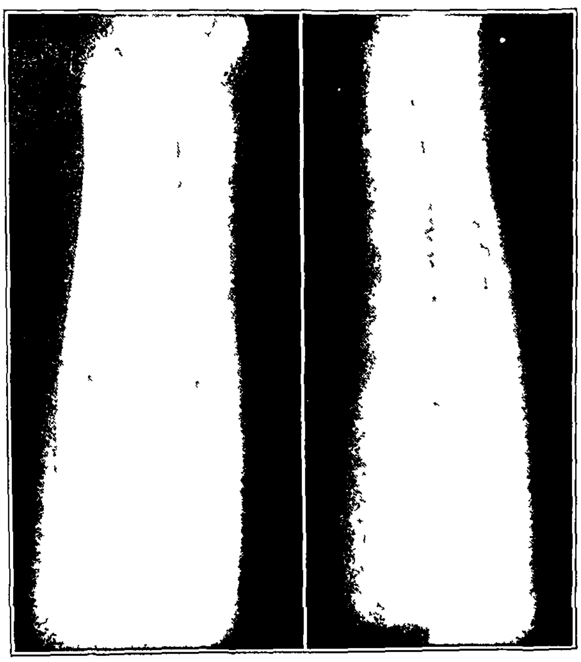


FIG. 6-A

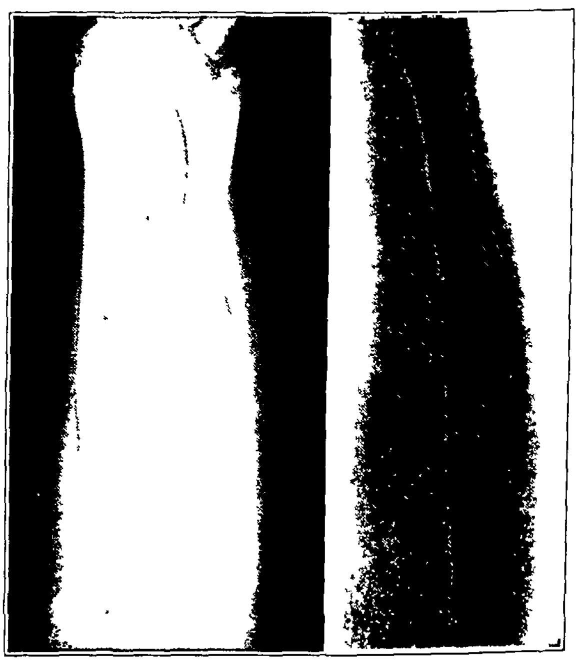


FIG. 6-B

Fig. 6-A: Before grafting.

Fig. 6-B: After grafting. Method of fixation of iliac graft in non-union of ulna. Iliac graft was readily applied and held by turned-up cortex of recipient bone. Union was rapid. (*Letterman General Hospital Photographic Laboratory.*)

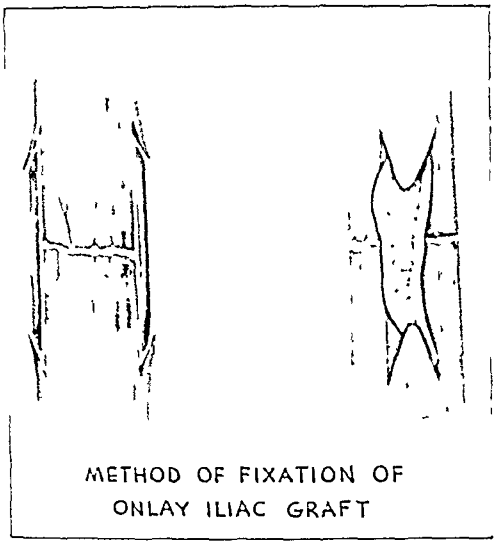


FIG. 7

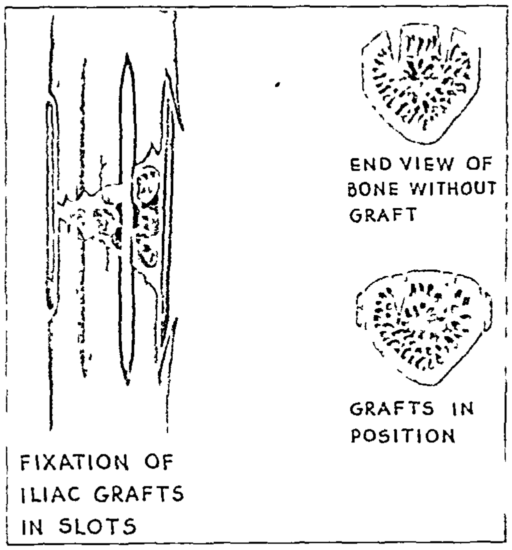


FIG. 8

Those cases in which union takes place across a small bridge of bone (Figs. 2, 3-A, and 3-B) and those in which there is contact between two bone fragments, even though it is minimum and the union is by fibrous tissue (Figs. 4-A and 4-B), are ideal cases for the use of cancellous bone from the ilium. If the non-union is such that the position of the fragments could be maintained properly with a plaster cast after surgery, one should not hesitate to use cancellous bone. In some cases, wedging of the cast is necessary after operation to obtain the necessary alignment. In some of the long bones, such as the radius and the ulna, large gaps can be bridged with strips from the ilium and maintained with screws (Fig. 5). It is believed that iliac bone could be used more extensively in non-union of the long bones, especially the radius or ulna, where there is loss of bone substance for some distance. By cutting a large graft from the ilium, one can apply it in onlay fashion and use screws for fixation and maintenance of reduction, just as with cortical bone.

In those cases with a fairly large bone defect, in which reduction cannot be maintained by the iliac grafts and cast alone, a large graft of tibial bone can be applied, in addition, in onlay fashion; and the position of the fragments can be maintained with screw fixation. The iliac graft then serves to fill the defect. Only very rarely has a metal plate been substituted to maintain reduction.

Horwitz and Lambert have used a metal plate for fixation and then applied grafts around the site of the non-union. A cortical graft is more physiological and, if properly immobilized in plaster, is not liable to fracture. The authors have used a plate only, combined with a graft occasionally, in non-union of the upper part of the femur, where it was felt that the stress was more than a strip of tibial bone could withstand.

A number of patients have been seen who were treated elsewhere by plating and the introduction of iliac grafts. In many of these cases the plate had taken all of the stress and strain, and as a result the iliac grafts had become absorbed. This has been observed most frequently in cases in which there has been loss of bone substance. With this observation in mind, the authors feel that, when internal fixation is needed, a tibial graft plus iliac strips is more physiological and much more likely to produce union than is the procedure of plating and insertion of iliac grafts.

The use of dual plates and grafts around the plates, as described by Key, is seldom, if ever, indicated. Patients have been seen in whom dual plates had been applied for fresh fractures in the tibia. When these patients were later seen by the authors, the plates had to be removed. When iliac grafts are used, rigid fixation of the grafts is not a problem.

Plaster immobilization has always been sufficient (Figs. 6-A and 6-B). The use of plates and screws before the grafts are applied calls for considerable stripping of the soft tissue and periosteum, which, in turn, means a delay in healing.

The size and shape of the iliac grafts and the means of fixation vary with the nature of the non-union and also with the bone involved. The method of removal of the iliac strips has been described by Abbott. In some instances the authors applied them in onlay fashion, chiseling away only a portion of the recipient cortex. In other instances the cortex is partially elevated at one end and attached at the other. The attached portion of the cortex is then used to hold the graft in position (Figs. 6-A, 6-B, and 7). In other cases the grafts are wedged into slots produced by an osteotome (Fig. 8). This method prevents excessive stripping of the periosteum and is especially applicable where the bone of the recipient area is quite osteoporotic or naturally cancellous, since it is easy to produce a slot in these areas. In still other cases the strips are intramedullary in one fragment and applied in onlay fashion on the adjacent fragment. This procedure is used especially in cases in which the non-union is in the vicinity where the bone normally flares, such as at the end of some of the long bones. A combination of the methods described is used in most cases. Chips of cancellous bone are usually placed about the site of non-union.

Many surgeons believe that rigid fixation is essential for rapid bony union. Murray has been a strong advocate of rigid fixation of the graft. Phemister,[18] on the other hand, has maintained that, if the graft can be held adequately by soft tissues, screw fixation is unnecessary, provided a plaster cast will immobilize the fragments well. In a number of instances of unstable fibrous non-union, iliac grafts have been applied across the site of non-union, as described, and immobilization has been maintained with only a plaster cast. Union was rapid in every case. If the soft tissues will hold the graft in position and if reduction can be maintained by a cast alone, screw fixation of the graft is not essential. On the other hand, if reduction is difficult to maintain and if the soft tissues will not hold the graft in a satisfactory position, as is frequently the case in non-union of the radius and ulna, internal screw fixation should be used.

As a rule the scar tissue has been curetted out from the site of non-union. In some instances there was danger of a flare-up of an old infection, so the scar was left intact or only partially removed; union progressed without delay in each instance. Phemister [18] has shown that removal of the scar tissue is not necessary for the establishment of bony

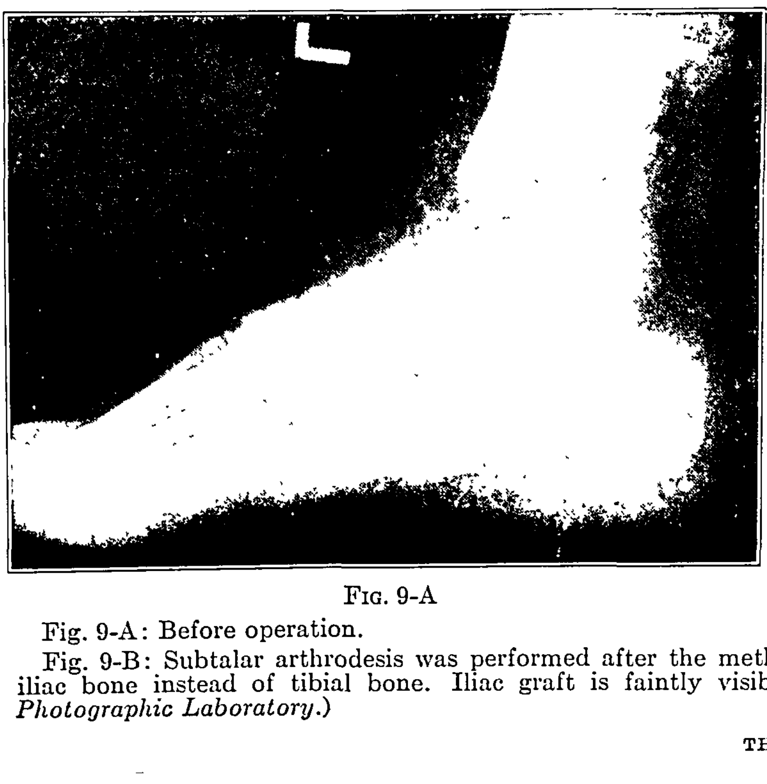


FIG. 9-A

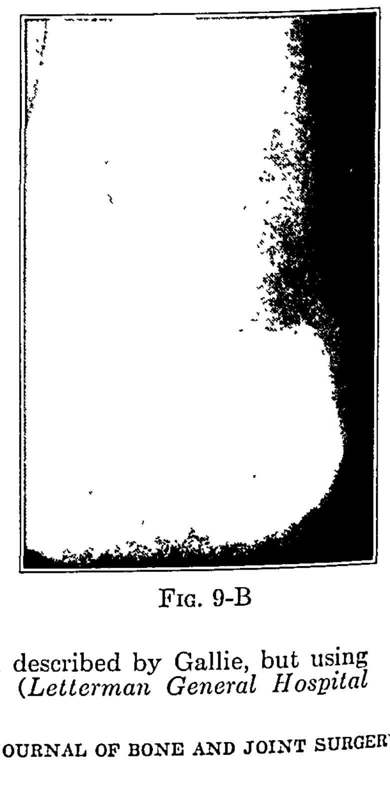


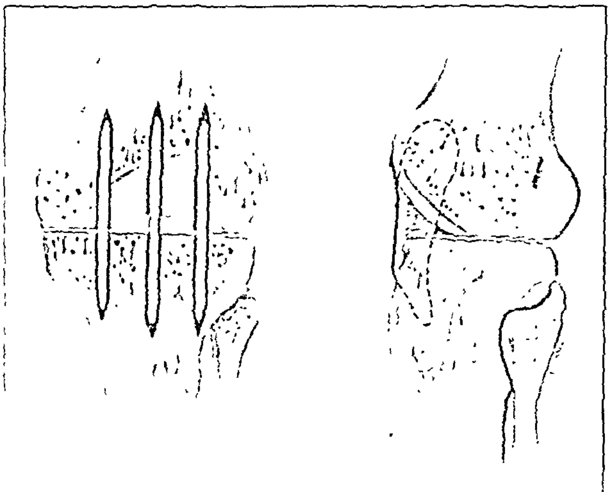
FIG. 9-B

Fig. 9-A: Before operation.

Fig. 9-B: Subtalar arthrodesis was performed after the method described by Gallie, but using iliac bone instead of tibial bone. Iliac graft is faintly visible. (*Letterman General Hospital Photographic Laboratory.*)

union. Once the graft has been united at both ends, the intervening tissue ossifies, as described previously. Many authors advocate complete removal of the fibrous tissue from the site of non-union [4,15].

Minimum soft-tissue dissection about the site of non-union is most important. Haldeman has shown experimentally that excision of the periosteum from the ends of the bone fragments delays callus formation and ossification. Phemister [20] has observed that excessive periosteal stripping leads to a delay in ossification. The authors have done a minimum amount of soft-tissue dissection in these cases. When using iliac bone, one frequently is able to insert the grafts in slots or in onlay fashion by raising a portion of the cortex with its intact periosteum. Thus there is a minimum degree of interference with the periosteum.



ARTHRODESIS OF KNEE USING ILIAC GRAFT

Fig. 10

USE OF ILIAC BONE IN ARTHRODESIS

Strips of cancellous bone from the ilium have been used very satisfactorily in arthrodesis of the wrist, knee, and subtalar joints. In subtalar fusions, the method described by Gallie has been used. His original description advocated a posterior approach; removal of a truncated wedge of bone from the subtalar joint; and insertion of two pieces of tibial bone, cortex to cortex, into the defect. Instead of using tibial bone, the authors employ cancellous bone from the region of the posterior superior spine of the ilium (Fig. 9-B); in seven cases fusion has been by this method. Roentgenograms of the subtalar joint, taken soon after arthrodesis had been carried out in this manner, show very little change from those taken before operation; therefore, one must be on guard when interpreting these films. Replacement of the iliac transplant is more rapid than is replacement of the tibial transplant employed by Gallie.

Fusions of the wrist were done, using iliac bone, as described by Abbott, Saunders, and Bost. The technique is not difficult and excellent results have been obtained.

In war injuries about the knee, not infrequently the patella and most of one femoral condyle may be shot away. Arthrodesis of such a joint presents a problem, because joint resection and removal of the remaining condyle to obtain maximum bony contact produce undue shortening. To arthrodese such a knee, we have resected the joint and bridged the gap where the condyle is absent, as well as where the tibia and femur come into contact with iliac bone (Fig. 10). Three or four strips of iliac bone are driven into a slot across the joint anteriorly (Fig. 11-B). When firmly wedged into a slot, these iliac strips provide immobilization and, more particularly, aid fusion. By immobilizing the joint with pins, the grafts can be inserted with relative ease. The insertion of iliac grafts is justified in knee arthrodesis, even though both condyles and the patella are present. Knee fusions frequently are slow, and anything that will speed up the process is time saved for the patient. The method employed in knee arthrodesis is shown in Figure 10.

RESULTS

The total number of bone grafts done for non-union and the donor bone used are indicated in Table I.

TABLE I

BONE GRAFTS FOR NON-UNION

Bone Grafted	Donor Site: Local (Sliding or Chip Grafts)	Tibia	Ilium	Radius or Ulna	Total
Clavicle		1			1
Humerus		7	2		9
Radius		5		1	6
Ulna	4	8	3		15
Radius and ulna at same time		3			3
Navicular			2	2*	4
Metacarpal		12		13	25
Phalanges		3		4	7
Femur					
Neck	3				3
Upper portion	2	6	7		15
Mid-portion		4	5		9
Lower portion		4**	7		11
Tibia					
Upper portion		2†	7		9
Mid-portion	2†	7	6		15
Lower portion	3	6	6		15
Medial malleolus		16			16
Metatarsal		1			1
Totals	14	85	45	20	164

* Cancellous portion used.
** Tibial and iliac bone used in one of these cases.
† Chip grafts (Cowan's method).

As a rule, the iliac grafts were done late in the series. Experience has revealed the wide range in which iliac grafts can be used, and thus the authors are now using them more extensively than previously. At present, many metacarpal grafts are being done with iliac bone, whereas previously the ulna or tibia was used as the donor site.

Tibial bone was used rather frequently in arthrodesis, particularly in fusions of the ankle, tibiocalcaneal fusions, and those of the tibia, talus, and calcaneus, because of its ease of accessibility and the support it produces (Table II). The use of iliac grafts in arthrodesis has already been discussed.

Of the 228 cases operated upon (by graft or arthrodesis), there was a flare-up of latent infection in twenty-two instances (Table III). *However, union was obtained in seventeen of these cases in spite of the infection.* Most of the flare-ups were either mild or moderate. In these seventeen cases the drainage either subsided spontaneously or, in a few cases, a few small sequestra were removed from the wound, after which drainage eventually ceased.

The histories revealed that not infrequently the flare-ups following surgery were in individuals who had had no drainage for six months prior to surgery. In most cases three months after subsidence of drainage is a safe time to proceed with bone-grafting. However, a longer delay will do no harm. Since none of the donor sites became infected, and since all of the postoperative infections occurred in association with old compound fractures, the infections were considered to be the result of flaring up of a dormant process in the wound, rather than the introduction of new bacteria at the time of operation.

Failures of arthrodesis or bone-grafting occurred in thirteen cases (Table IV). A few of the cases listed were presumptive failures and may be successful eventually. These patients were transferred to other hospitals, so that we were unable to follow them sufficiently long to determine the ultimate outcome; therefore they are listed with the failures at this time. There were five failures due to infection; one of these patients was not oper-

TABLE II

ARTHRODESIS

Arthrodesis	Donor Site				Total
	Local or None	Tibia	Ilium	Radius	
Spine	2		2		4
Shoulder		2			2
Wrist		1	3		4
Metacarpophalangeal and interphalangeal	4			3	7
Knee			2		2
Ankle		5	1		6
Ankle and subtalar		4			4
Triple arthrodesis	9				9
Subtalar			7*		7
Tarsal	1	3			4
Interphalangeal	11	1			12
Tibiocalcaneal fusion (following astragalectomy)		3			3
Totals	27	19	15	3	64

* After method described by Gallie, but using iliac bone.

TABLE III

INFECTION IN CASES OF GRAFT AND ARTHRODESIS

Degree of Infection	Donor Site			Results	
	Ilium	Tibia	Other Locations	Failure	Solid Bony Union
Mild	5	4	2	0	11
Moderate	3	2	1	1	5
Severe	1	3	1	4	1
Totals	9	9	4	5	17

ated upon by the authors at the time of the flare-up. One of these five cases was an arthrodesis, and the other four were cases of bone-grafting.

One of the cases of infection occurred in an attempted arthrodesis of the distal joint of the large toe. Progress was slow following infection, so that the distal end of the toe was amputated; the patient suffered no disability. In another case listed as a failure, iliac strips were laid in a granulating wound and the skin margins were brought together over the graft. Although it is sometimes advocated, we feel that this procedure should be discouraged. Infection, even though mild, is almost certain to result and to persist for some time.

Another failure was in an attempt at arthrodesis of the interphalangeal joint of the large toe. Originally, the cartilage was removed and the position was maintained by placing a Kirschner wire through the two phalanges. At the second operation a tibial peg was driven across the joint. In a similar case in our series, fusion was very slow when only the cartilage had been removed. Since the graft adds very little to the difficulty of the operation, the authors feel now that this should be done originally in all cases of this kind.

A second graft of the phalanx was done in two cases. In one the graft was solid, but the operation was repeated to correct a faulty position. In the other case a tendolysis was

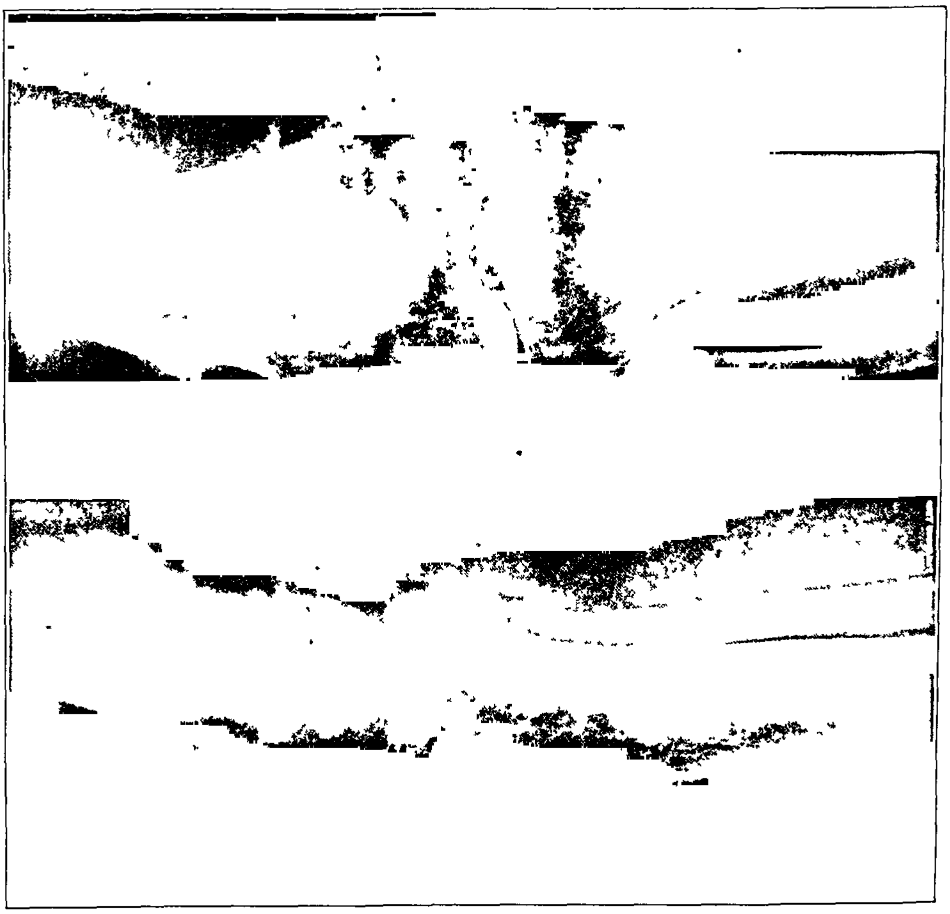


Fig. 11-A

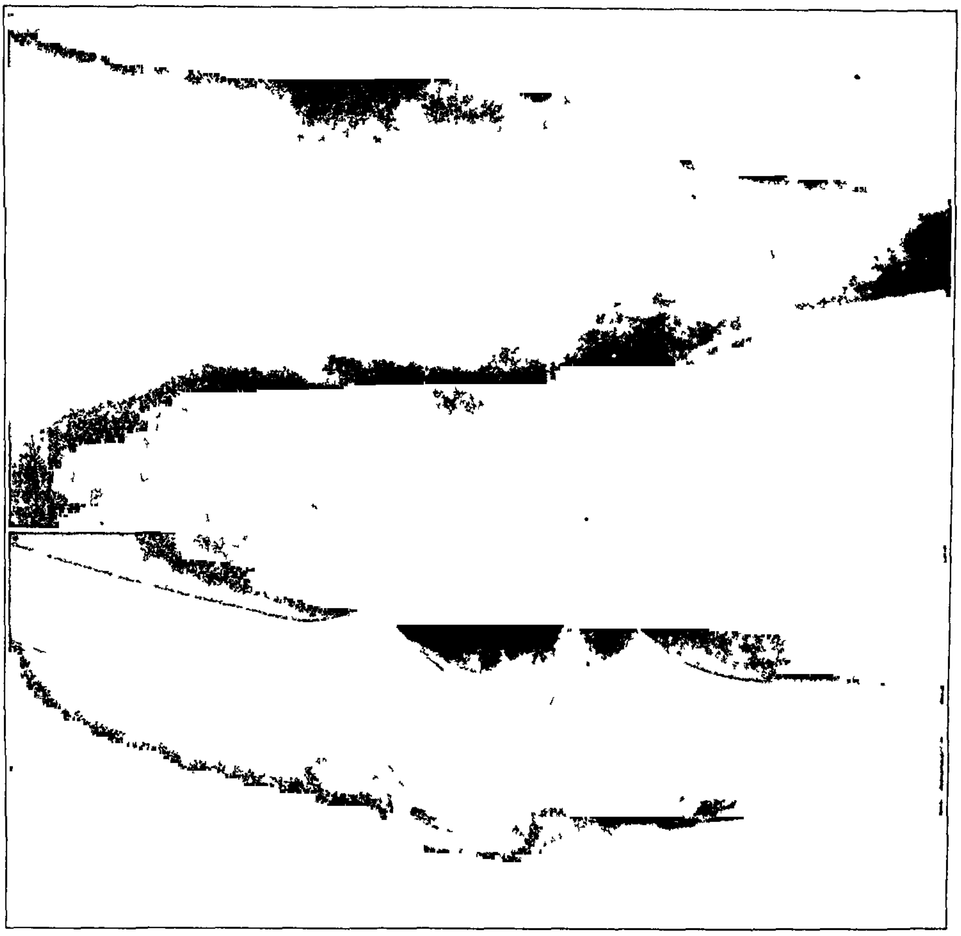


Fig. 11-B

Fig. 11-A. Before operation.
Fig. 11-B: Arthrodesis of knee has been performed, using iliac strips to bridge joint.

TABLE IV
FAILURES OF BONE-GRAFTING AND ARTHRODESIS

tient	Bone or Joint Involved	Donor Site		Infection	Remarks
		First Graft	Second Graft		
N.	Ulna	Local chips	Tibia	None	Excellent result following second graft.
T.	Ulna	Tibia	Tibia	None	Original graft fractured and pseudarthrosis developed.
'B.	Phalanx	Ulna	Tibia	None	Regrafted, because of faulty position. Original graft solid, however.
.R.	Phalanx	Ulna	Radius	None	Tendolysis done two months after first operation; bone not solid, so additional small graft done. With more time this would probably have united without additional surgery.
H.	Femur	Tibia	Not done	Present	Some mild angulation Not able to follow patient long enough to determine if solid. When last seen, union was progressing.
.M.	Femur	Tibia	Ilium	None	Original graft fractured. At second operation the old tibial graft was replaced and iliac strips were used in addition. Union progressing when patient was last seen.
P.	Tibia	Tibia	Tibia	Present	First graft done elsewhere; failure due to infection After second graft, some wound separation.
L.	Tibia	Ilium	Not done	Present	Iliac strips laid in granulating wound and skin brought over grafts Wound separated.
[.G.	Ankle	Tibia and fibula	Not done	None	Satisfactory clinical result, but no bony union.
K.	Ankle	Fibula	Not done	None	Satisfactory clinical result, but no bony union.
M.	First metatarsal	Tibia	Not done	Present	Drainage following surgery, so graft removed.
.W.	Inter-phalangeal joint of large toe	None	Not done	Present	Tip of toe amputated eventually; no disability of foot
I.L.	Inter-phalangeal joint of large toe	None	Tibia	None	Originally, cartilage removed and immobilization obtained by Kirschner wire At second operation, tibial peg driven across joint.

rformed, two months after the graft. Motion was noted at the time of this operation, so at an additional small graft was inserted. More time would probably have brought about ion.

SUMMARY

Elimination of infection by early and frequent surgical intervention is most important the treatment of infected compound fractures. Early coverage of the wound aids ma-ially in two ways: First, as soon as the wound has been covered with skin and scar tissue, oliferation ceases; thus there is less soft-tissue damage and less joint stiffness. Second, ne-grafting can be done at an earlier date, due to the fact that infection has been minated early.

The soft-tissue coverage must be adequate before grafting is done. Unless split-skin afts have considerable subcutaneous fat and muscle between them and the bone, they will t withstand the strain when exposure is made through them. Therefore, pedicle grafts ust be used in many instances to replace poor skin.

With the use of penicillin, bone-grafting can be done three months after the cessation drainage, if all other factors are favorable.

The type of bone graft varies with the circumstances. Whenever possible, iliac grafts ould be used, since they are usually applied easily and replaced rapidly. Foreign mate-

rial for internal fixation is necessary only when the fragments and the graft will not remain in position without internal fixation.

Iliac grafts aid materially in arthrodesis, particularly of the wrist, knee, and subtalar joints, and the small joints of the hand. The authors have had no experience in employing iliac bone in the stabilization of other joints.

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FACTORS INFLUENCING CALLUS FORMATION IN OPEN FIXATION OF FRACTURES *

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The object of this paper is to consider the factors which, due to the surgeon's operative interference, may influence the speed of formation of callus and its quality and quantity. Only the factors related to surgery are considered, and not the nature of trauma, the location of the fracture, the state of health of the patient, or his age. A presentation of the still widely discussed theories on the histology and biology of bone formation is not included. Due to circumstances, proper illustrations and statistical data are, unfortunately, lacking.

THE SIGNIFICANCE OF THE TIME OF OPEN FIXATION

The surgeon may operate upon fractures at different intervals after their occurrence. The time of operation may have marked influence on the callus, and will be considered in two groups of cases: cases of fresh fracture and those of old fracture.

Fresh Fractures

In the group of fresh fractures are included all fractures in which the process of callus formation has not been definitely concluded.

The histological and biological processes which take place at the site of the fracture, before healing can occur, are well known: the resorption of dead tissues; the organization of the soft parts, including the hematoma, into a network of fibrin and young connective tissues; the mobilization of mineral salts from the fragments; and especially the building of a new network of blood vessels, which will guarantee the transportation of the needed chemical supplies. This important transformation, without which the solid union of bone *cannot* take place, occurs in an acid medium and requires from eight to fifteen days. Only after its completion does the pH become alkaline and allow the precipitation or the fixation of mineral salts.

From these well-established facts, one can arrive at three important deductions, which are amply confirmed by observations:

1. If the surgeon decides upon open fixation, and if the time can be chosen, the most favorable moment will be as soon as possible (emergency operation) after the fracture has taken place. In this way the dead tissues will be removed surgically; the periosteum and the soft parts will be replaced immediately in their anatomical positions, close to the site of the fracture; and an optimum supply of blood will be assured. There will be a minimum chance of infiltration of the muscles, which will give them a quicker restoration of function; this, in turn, means better circulation around the fracture. The delicate building up of the pre-osseous connective tissue will take place under the best anatomical and physiological conditions; and, finally, if the operation has been technically perfect, there will be no need of external immobilization. If external immobilization can be abandoned, an optimum restoration of circulation will result from function of the muscles and joints. Under these circumstances, the callus will be of minimum size (with very little bridging inside or outside the cortex); it will develop at maximum speed, for the blood supply will be good; and it will be in an optimum location (in the line of fracture).

2. Open fixation which is performed between this emergency period and approximately the fifteenth day after fracture necessitates operating through infiltrated muscles, the destruction of the delicate formation of young connective tissue and of the new vascu-

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larization, and the stirring up of local mineral metabolism. Nature's work is destroyed in its making and it must be started again, with a new response to a new trauma. Open fixation performed at this time—thus *delayed*—usually gives rise to more extensive callus and slows down the process of repair.

3. Operating after the period of restoration (eight to fifteen days after fracture) means operating in an alkaline medium and destroying connective tissue which is already differentiated. It interferes with the mineral metabolism at a time when minerals are already being deposited in the new bony structure. It implies the destruction of the new vascular network. It is more or less like operating in scar tissue. It retards still more the formation of callus, and may even impair seriously the formation of new bone. It takes eight or ten months for the line of fracture to disappear in a retarded or late open fixation, whereas it takes only four or five months when fixation is done as an emergency measure.

Old Fractures

Included in this group of cases are the ununited fractures with more or less demineralization, and the malunited fractures. In both types of cases, the outstanding feature might be called "inertia" of the bone.[17] This lack of response to surgical interference varies greatly from case to case and depends mostly upon the blood supply. It also compels the surgeon to use artificial means of providing new supplies of mineral, such as bone grafts; and technical procedures, which will be described later.

A few observations which may be significant in the development of callus in old fractures are as follows: (1) The formation of callus is influenced by the addition of fresh bone and also by the stirring up of bone at the site of the fracture. (2) The development of callus is often extremely slow, sometimes almost non-existent; means of stimulating bone formation are still being investigated. (3) In delayed union or in non-union of a diaphysis, one fragment is always more demineralized than the other. (This is of technical importance.) The fragment in which demineralization is greater usually gives rise after operation to more bone than the other fragment. (4) In fractures of the two bones of one limb, one of the bones is usually more demineralized than the other. (5) Spontaneous demineralization of the corresponding bone of the other side has been observed.

THE IMPORTANCE OF REDUCTION

If open fixation of a fracture has been performed at the optimum time, the reduction of the fragments will have a bearing on the rapidity of callus formation, the shape and the amount of callus.[3]

Rapidity of Callus Formation

The rate of callus formation is influenced greatly by the coaptation of the fragments. The more nearly the fragments are in contact, the quicker the line of fracture disappears. This has been observed in many cases.

In plating the two bones of the forearm, there is always a slight difference in coaptation between the two bones, in spite of the best technical ability; this is emphasized in old fractures if the plating is done after resection of the four ends of the fragments. The bone in which the reduction is better will almost always heal first.

Three patients with similar non-union of the radius were operated upon by the author on the same morning. The rate of disappearance of the line of fracture in these cases coincided exactly with the degree of coaptation. Another patient was operated upon for non-union of both tibiae. Both legs were in a similar condition; both were operated upon by the same procedure, external fixation. The postoperative course was uneventful on both sides. One side showed a perfect coaptation of the fragments; the other side showed a separation of about two millimeters. The first side healed clinically and, according to the roentgenographic examination, exactly twice as fast as the other side.[12]

The Shape of the Callus

The shape of the callus also varies with the perfection of the reduction. This was noted especially in the cases just mentioned. If the two cylinders of compact bone are in perfect contact, bone usually forms between them and very little forms on the outside or the inside. If there is a space between the two cylinders, new bone will form first around the line of fracture (bridging) and only later between the layers of cortical bone. Theoretically, and often practically, the amount of bridging depends upon the amount of separation of the fragments and is proportional to it.

Amount of Callus

The amount of callus is also influenced by the degree of reduction. The poorer the reduction, the larger the callus.

THE INFLUENCE OF FIXATION

If a fracture has been operated upon at the optimum time and the reduction has been perfect, the rapidity of callus formation, its quality, and its quantity will depend upon the degree of fixation of the bone fragments. The perfection of fixation is much more important than the time of operation and the perfection of the reduction. Fixation depends almost entirely upon the surgeon, the method he uses, the type of material he uses, and his technique.

A few methods will be enumerated which do not give adequate fixation, and then one will be mentioned which does give fixation:

Insufficient Fixation Due to the Method

External fixation, which was first used by Malgaigne during the last century, was later perfected and was officially presented by Lambotte in 1902. Since then, it has been the subject of much experimentation and discussion. The method consists in fixing a fracture of a diaphysis by pins or screws, held together outside the body by a bar. For mechanical reasons, the two proximal screws must be inserted as near as possible to the line of fracture and the two distal screws as far as possible from it. In spite of this mechanical device, a certain degree of mobility remains, even when the reduction is perfect. Surgeons who use this method know that bony union is delayed because of the lack of complete immobilization. For this reason, and because of the danger of infection, many surgeons have abandoned the method. External fixation, however, still remains the best method of treatment of bad compound and comminuted fractures with extensive laceration of the soft tissues.[13,15]

When both bones of the forearm have been fractured, a plate should be applied to each. Surgeons still apply a plate to one bone, however, and are satisfied to leave the other bone alone if the fracture has been well reduced. They are aware that the procedure is insufficient, and therefore they always add a plaster-of-Paris cast. In spite of the cast, the bone which is not held by a plate will always show delayed union, and sometimes even non-union. This is definite proof of the important effect of fixation on callus formation.

In spite of good reduction and strong plating, the results of open reduction of fractures of the tibia have not been satisfactory, because of a slight mobility due to sheering. The author therefore decided upon the intramedullary placement of a small bone peg at the line of fracture, and later advocated plating of the fibula.[8]

In an open fixation, a surgeon's technique must be such that complete immobilization of the fragments will be achieved. In that respect, cross fixation through the line of fracture, added to plating (a method which we probably owe to Clay Ray Murray), has been a valuable contribution to fracture surgery. By the quick formation of callus, the rapidity of disappearance of the line of fracture, and the optimum amount of bone formation, this method has proved that fixation is the most important of the factors which may influence callus formation in open fixation of fractures.

Insufficient Fixation Due to the Type of Material

A surgeon may perform an open fixation of the femur with plating. In spite of a perfect technique and an uneventful postoperative course, without fever or pain for days or weeks, the following symptoms may suddenly develop: slight rise in temperature, slight deformity of the thigh, a moderate swelling, and a moderate amount of pain. Under these circumstances, the surgeon may be sure that the plate is either bent or broken.

If the plate bends, mechanical insufficiency is usually the cause. The amount of metal inserted at open fixation does not matter. For the femur, a plate should be used which is at least two millimeters thick and not perforated at its middle portion, which would be in the line of fracture.[9] The addition of cross fixation will help greatly to prevent bending. If one attempts to correct the bend under anaesthesia and to immobilize the thigh in a plaster-of-Paris cast, the callus will usually develop quickly and become rather large. A sort of "reactivation" takes place at the site of fracture.

If the plate breaks, the complication is more serious. Breaking of the plate is always due to a defect in the metal. It may have been tempered for the sake of solidity, which is a mistake. It may contain impurities or it may have been rendered brittle by manipulation, most often by hammering or by constant vibrations.

The author's experience included a series of broken plates in consecutive cases. The metal used was Krupp's stainless steel V-2A, which had previously given satisfaction. An abnormal reaction of bone against certain parts of the plates, mostly at the tips of the screws, was noticed. All the plates came from the same stock. An examination of the steel was made. The crystals were regular and homogeneous, which proved that there had been no fault in the manufacture; but many microscopic specks were present between the crystals, and these specks were suspected to be impurities of carbon or high-carbon steel, which probably provoked electrolysis.

Insufficient Fixation Due to Technical Factors

A few of the most important examples are as follows:

Loosening of Screws: One or more screws on one fragment may become loose, and slight or even serious complications may result. The callus formation is slowed down because of the lack of immobilization. Formation of extra bone may occur around the loose screws and also around the loose end of the plate. There are several possible causes of this troublesome complication:

1. The drill may have been a trifle too large, and the screw may have moved in its canal. A space would then exist between the surface of the screw and the surface of the canal.

2. The drill may have been a little too small, and the screw may have been inserted under pressure, especially if a mechanical screw driver was used. This abnormal pressure would cause resorption of bone.

3. The size of the drill may have been perfect, but the bone may have been hard. This is often true of old fractures. Here, also, the screw may have been inserted under pressure. In certain instances, the self-tapping screw is insufficient, because the tap end is too soft. A tap should be made of hard steel, preferably of tempered steel. Perfect tapping will allow the screw to reach the opposite cortex in line with the exact point of penetration and in the right direction. In a large bone, the self-tapping screw might make its own thread through the first cortex in a slightly oblique direction; it then would reach the second cortex at the wrong point and in the wrong direction.

4. During its insertion, the thread of the screw may have rubbed the edge of the hole in the plate and sustained microscopic damage. The damage might be enough to destroy the homogeneity of the metal and to provoke electrolysis along the edge of the screw. If there is any bone reaction to the stainless steel, it is almost always found at the tip of the screw or on the edge of the groove. In the latter site, the sharp end of the screw driver

often skids and damages the metal. In such cases a local destruction of the head of the screw is found, covered by a cap of new bone. Cultures made from this region remain negative. This observation shows also why the metal should be polished, should be without a scratch, and should be handled with smooth instruments and without force.

Insufficient Fixation of Plate: A plate should never be fixed to a bone with only two or three screws. Motion in the region of the fracture would result and there would be danger of delayed union or of non-union. This result of insufficient fixation of the plate has been observed many times. If only four screws are used, two of them should be inserted as nearly as possible to the line of fracture, especially if cross fixation cannot be employed; the other two should be at the very end of the plate.

Deficient Contact Between Plate and Bone: The contact between the plate and the bone surface may be deficient; in this event, there will be an empty space between the plate and the bone. This space is filled at first with fluid and blood, and later with new bone; it will delay the formation of callus in the line of fracture. When necessary, the transverse and longitudinal curves of the plate should be computed mathematically, so that the plate can be adapted perfectly to the bone. Furthermore—and this is especially important in cases of fracture with several fragments—during the insertion of the screws, the entire length of the plate must be maintained firmly against the bone. This can be accomplished only by the use of several bone clamps,—sometimes three or four. The author has devised a handy, simple, light clamp which can be used with one hand.[16] The clamps must be handled without force, so that, when they are removed, there will be no abnormal pressure on the screws. If the fracture is composed of several fragments, only the use of several bone clamps will permit a perfect reduction and thus fulfill the conditions for an optimum callus.

Short Plate: To answer the mechanical requirements, the length of the plate for the tibia should be at least equal to three times its width and, for other bones, four or five times their width. Otherwise, the pull of the muscle will exert abnormal strain on the screws of at least one fragment. This is true in cases of fresh fractures. On the other hand, if the bone is demineralized, the plate should be as long as necessary, and in certain cases should equal the whole length of the diaphysis. The quantity of metal matters little. The number of screws inserted should vary according to the degree of demineralization of the fragments and the length of the fragments, if the fracture is near the epiphysis.

Comment: The Küntscher method, which has recently been widely used in Europe, consists in inserting a wide pin through one end of the bone, along the whole length of the diaphysis.[4] Garcia Portela, in his review of 470 cases, proved that, contrary to the experiments on animals, the callus forms quickly, is only moderate in amount, and includes a periosteal and an endosteal reaction.

If an orthopaedic surgeon is confident of his technique, he should refrain from applying a plaster-of-Paris cast after open fixation, since this is detrimental to the function of muscles and joints. This function is an important factor in keeping a constant active local circulation of blood, which is one of the determining elements in securing a prompt and optimum callus.

THE USE OF BONE-GRAFTING IN OPEN FIXATION

In general, bone-grafting in open operations is only of help in securing callus in old fractures in which there is little or no response,—in other words, in which there is more or less "inertia" of the bone. In certain cases, bone-grafting may be compared with skin-grafting because it "fills the gaps" and assures bony contact in cases of bone defect; but its main value lies in its source of minerals and its improvement of vascularization. It may incidentally help fixation, but *only exceptionally should it be used as a means of fixation.* In other words, in open fixation with bone-grafting, even with massive grafts, metal fixa-

tion should be used as well, so that, except in unusual cases, one should not have to rely on plaster fixation, which is harmful for the production of callus.

Cortical Bone Grafts

Cortical bone grafts may be used as intramedullary grafts, extramedullary grafts, or grafts between fragments.

Intramedullary Grafts: Many surgeons believe that the insertion of massive grafts of cortical bone in the medullary cavity is harmful, because they destroy bone marrow and interfere with the blood supply. After extensive use of this type of graft, however, the author believes that it hastens the formation of callus and even provokes the formation of large, sometimes enormous, callus. The enormous callus which forms is one of the reasons why this type of graft should be discarded as a method of treatment of fresh fractures. The author employs intramedullary grafting of massive cortical bone as a routine procedure in two circumstances:

1. It is used in cases of non-union of long duration, accompanied by extensive demineralization. The graft, which is usually taken from the crest of the tibia, should vary in length according to the degree of demineralization. This type of graft offers three advantages in these cases: First, it increases the solidity of the plate fixation; the screws inserted through the two demineralized cortices find a strong support in the solid graft (a tap must be used). Second, it prevents too much shortening by keeping the ends of the bone slightly separated and also it prevents the formation of fibrous tissue between the fragments. (Chips of cancellous bone should be added in this area.) A third advantage is that it supplies the demineralized bone with a large source of mineral salts. The callus obtained when an intramedullary graft is used in cases of non-union is usually slow in forming, but it is solid and never excessive in amount if there is no motion in the screws and plate. The plate should be as long as the diaphysis, and the screws should be inserted obliquely to one another. A new type of plate was therefore devised by the author.[16]

2. The intramedullary graft is also used in cases of malunited fractures with dense bone tissue, or in cases of shortening of a bone after resection of a fragment. In these cases, the callus is sometimes slow to form, and the newly cut ends of bone do not fit perfectly. These two reasons, together with the ones just mentioned, justify the insertion in the medulla, at the line of fracture, of a short bone peg. Without doubt, this procedure activates the formation of callus. A longer bone graft would provoke too much reaction.

Extramedullary Grafts: The graft may be an inlay or an onlay graft. Both methods of grafting usually thicken the bone considerably, and may give rise to massive bone callus. Nevertheless, the extramedullary graft has to be used in certain cases, especially when the medullary cavity is small, as in the bones of the forearm or the clavicle. The freshening of extensive portions of the bone surface is one of the causes of the extensive bone reaction. This may sometimes impair function, as in old fractures of the forearm. A great risk is involved in using such a graft or in relying upon it for fixation, even with the use of a plaster cast. Proper plating must be added to it and, if the technique is good and the plate is long enough, the use of a plaster cast can be avoided.

Grafts Between the Fragments: If the formation of a large callus is to be avoided, as, for instance, in cases of defects of thin long bones like those of the forearm or the clavicle, a massive cortical bone graft of the same size as the bone can be inserted between the freshened bone fragments. Two essential requirements are imposed, however: The ends of the bone and those of the graft must be in absolute coaptation, and the plate must extend as far as possible.

Cancellous Bone

Cancellous bone is the most efficient bone for producing callus. There are two main indications for its use: (1) It may be used in cases of old fracture. Because of the inertia

of the bone in these cases, it is good always to place around the ends of bone a ring of chips of cancellous bone, taken from the same bone, from the tibia, or, better still, from the crest of the ilium. The callus formed will not necessarily be voluminous. (2) Use of cancellous bone is also indicated in certain cases of fresh fracture. A defect in bones due to the absence of a fragment, especially at the site of fracture, will always cause callus to form slowly and may be a serious risk of non-union. It is of primary importance that such a defect always be filled with chips.

Powdered Bone

Powdered bone can be produced by scratching, cutting, curetting, or drilling holes. It always promotes easy, fast, and abundant formation of bone. Its use should be avoided in fresh fractures, which should always be handled with smooth instruments. It will help greatly in cases of old fracture. In those cases, it is advisable to use a sharp, slightly curved periosteal elevator to separate the periosteum from the cortex, to scrape the cut surface of the bone with a sharp curette, to drill small holes at the ends of the fragments, and even to roughen the inside of the medullary cavity with a large drill.[9]

The author has had no experience with the influence of heterogeneous bone grafts and cadaver transplants on callus formation, and his experience with beef bone is too limited to be mentioned.

THE ROLE OF INFECTION

Infection *per se* is the dreaded enemy of the orthopaedic surgeon; yet its influence on the formation of callus cannot be overlooked. It is known that extensive acute infection will bring about necrosis and destruction of bone, and, conversely, that a mild staphylococcic infection is apt to produce extensive formation of bone, which in certain cases may reach gigantic proportions. The latter effect is probably due to a marked local activation of the circulation of blood.

In an effort to determine whether staphylococcic infection could be used to stimulate formation of bone, especially in those well-known cases in which the bone "will not react", a series of experiments on animals was started in 1926. These experiments proved definitely that the injection of cultures of attenuated staphylococci into the area of fracture greatly stimulates the formation of the bone.

THE NATURE OF THE METAL

If the callus is to be of an optimum type—that is, if it is to form quickly, become located exclusively between the ends of the bone, and not surround the material of fixation—attention should be paid to the nature of the metal. All surgeons agree that the use of an inert metal, such as stainless steel, is preferable; but too much emphasis should not be placed on this fact. In order to prevent unnecessary and abnormal reaction of bone, the most essential feature of the metal is that it be homogeneous. In other words, it should be, throughout all its mass, composed of similar crystals, without impurities, and deposited in regular layers. This is a question of manufacture. The metal should be polished perfectly, never hammered or filed, and should be handled with care, especially during the insertion of screws.

Several years ago the author used ordinary non-stainless steel, and has seen hundreds of cases in which Lambotte used it without any abnormal bone reaction whatsoever.

The effects of electrolysis on bone reaction remain mysterious. By mistake, the author used an aluminum plate and steel screws in an open fixation of the humerus. Healing took place in the normal way.[5,7,14]

Much more interesting is the effect of resorbable materials on bone.[11] In a previous study of the use of magnesium alloy on animals and in men as well (thirty-five cases), a series of factors were noted: The metal entered into solution as soon as it was inserted

into the tissues. It always provoked a minimum reaction in bone. This reaction was characterized by bone formation, the amount of which was identical with the amount of resorption of the metal. The reaction of bone was constant. If the metal crossed a joint, it left the joint surfaces undisturbed after its resorption. Unfortunately, the metal gave rise to the formation of considerable quantities of gas, which had to be evacuated at intervals.

A similar alloy containing more aluminum, which would prevent its being resorbed so quickly, might provide a useful means of provoking bone reaction whenever and wherever it is wanted.

OTHER FACTORS INFLUENCING CALLUS FORMATION

The other factors which I wish to mention all concern the speeding up of bone formation; they are only worthy of consideration if the two basic factors, reduction and fixation, have been carried out perfectly. Most of them deal with the increase of the blood supply.

Early Function

Early function is a basic factor which is only practical if no plaster has been applied. It can be carried out soon (fifteen days after reduction) in the upper extremities. It is the same for the lower extremities, but here the real function consists in weight-bearing, and the time such function should start varies according to the roentgenographic findings.

Sympathectomy or Ganglionectomy

Sympathectomy or ganglionectomy is useful only if block anaesthesia with procaine hydrochloride indicates definite improvement. Its value is temporary and not constant.

Massage

Massage may be harmful and may provoke marked reaction of the bone, as well as of the soft tissues. If it is applied gently, it may help in relieving muscle spasm.

Tapping

Tapping the site of the fracture or the extremities of the fractured limb will stimulate circulation of blood and hasten the formation of callus. Its effect is negligible, however.

Short-Wave Rays

These may stimulate the circulation if used in small amounts, but the danger of provoking resorption of bone outweighs their value.

Calcium

The oral administration of calcium, alone or in the diet, is inefficient. Calcium, injected intravenously or into the fracture area, does not seem to be popular among orthopaedic surgeons. Neither does the injection of the serum of patients with fractures.

Other Drugs

Parathormone and vitamin D have been advocated. The author has had no experience with them.

Bogomolets, in 1943, suggested the use of an "antireticular cytotoxic serum", produced by inoculating horses with cells of the spleen and bone marrow taken from fresh human cadavera. He claimed that in small doses the serum has a valuable effect on the speed of bone formation. The author has had no experience with it.

CONCLUSIONS

In the treatment of fractures, surgeons are striving for the optimum type of callus, exactly as they aim at obtaining a perfect skin scar.

The characteristics of an optimum callus are: (1) rapid formation; (2) its quality

(solid homogeneous bone); and (3) its quantity, which should be neither large enough to interfere with function (a large callus corresponds to a keloid) nor too small.

Surgeons have at their disposal most of the means of reaching their aim. The most important ones depend upon themselves, their principles, their methods, and their technique,—the "timing", the perfection of reduction and immobilization, the discriminating use of bone grafts, and so forth. In spite of attention to all these factors in particular cases of old fractures, surgeons will be confronted with a lack of response on the part of Nature; the bones "won't heal". (This should be the object of more research; and the author suggests the study of vaccines and of resorbable alloy.) All the means of effectively increasing the local supply of blood will be of help.

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FUSION OF VERTEBRAE FOLLOWING RESECTION OF THE INTERVERTEBRAL DISC

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Complete removal of the intervertebral disc has been advocated for disc protrusion, as well as for the treatment of spondylolisthesis. Some surgeons have also advised, in addition to removal of the disc, the insertion of a graft from the spinous process. It has been claimed that, by the removal of the disc, the vertebrae become fused and no movement is demonstrable three months later by maximum pressure on the spinous processes. It is further claimed that, when the broad surfaces of the bodies of the vertebrae unite, the fusion is just as perfect as by the most successful spinal graft. This union may be only fibrous at first, but it is considered sufficient to prevent any motion between the bodies of the vertebrae. It is assumed that eventually firm osseous union takes place between the bodies, but no definite proof has been presented to substantiate this postulate.

Opportunity for direct study of vertebral bodies after removal of the intervertebral disc is not available. Roentgenographic examination may be inconclusive, as minute changes are not discernible. It is known that bony fusion does not always take place after resection of the articular cartilage of other joints. Because of the difficulties just mentioned and because of inconclusive results as regards fusion of the bodies after removal of the intervertebral disc in human patients, studies in animals seemed warranted.

Accordingly, a series of six experiments were performed upon dogs of various ages, in which the intervertebral discs were removed at operation. It is not the purpose of this study to discuss the diagnostic criteria for the various disc lesions, the causes of these lesions, or the results which may be expected after removal of the entire intervertebral disc. The main problem is to determine what change takes place between the bodies after removal of the intervertebral disc. Certain other conditions will be considered, particularly the effect upon movement between the articular facets and between the spinous processes.

In performing the operation for removal of the intervertebral disc, the transabdominal approach was utilized, because it was thought that a more thorough removal could be accomplished with a direct, clear exposure of the disc. Also, it was believed that less sacrifice of the structure of the vertebral bone would be necessary in exposing the disc posteriorly in a dog.

EXPERIMENTAL DATA

Dog D-1, Aged Four Years

Experiment 1 was begun on January 17, 1945; the duration of the experiment was 146 days. At operation the disc between the fifth and sixth lumbar vertebrae was exposed through a mid-line abdominal incision. (The dog has seven lumbar vertebrae.) The anterior ligament was incised, and then the disc was resected and curetted as thoroughly as possible. The abdominal incision was closed in layers. No supporting dressing was applied after the operation.

At the end of 146 days the vertebral column was removed intact and was cleaned of its muscle. As seen from the abdominal side, the intervertebral space from which the disc had been removed was widened. There was a heaping up of osseous tissue on either side, but there did not appear to be complete bony bridging across the intervertebral gap. Roentgenograms showed the heaping up of bone, but not complete osseous bridging. On manipulation of the spine, there was found to be no movement between the vertebrae from which the disc had been removed; but free movement was possible between the bodies

FIG. 1

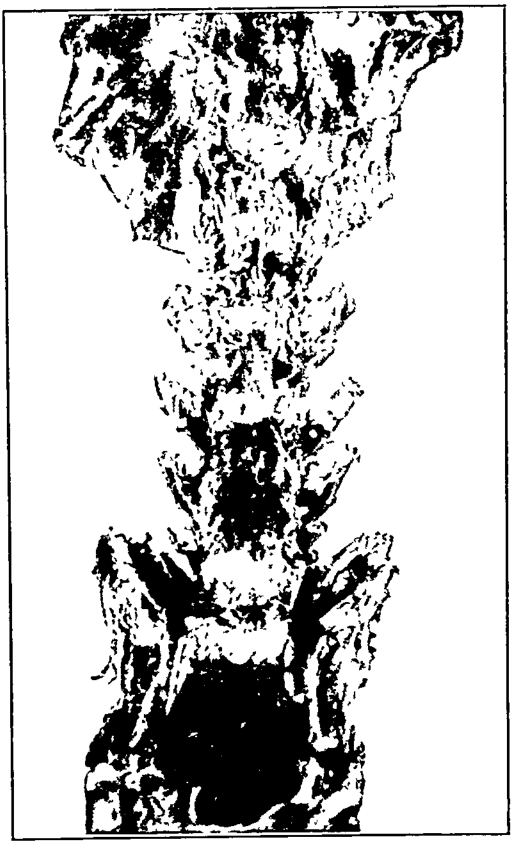

FIG. 2

Fig. 1: Dog D–1. Specimen has been split longitudinally, showing the heaping up of new bone on the abdominal side. Incomplete bony bridging in the resected disc.

Fig. 2: Dog D–2. Complete bony bridging between the vertebrae.

on either side. There was, however, very slight movement between the articular facets in the area of operation. Upon splitting the vertebrae longitudinally, a considerable heaping up of osseous tissue on the abdominal side was observed, but not complete bony bridging (Fig. 1).

There was an exudate about the nerve roots and in the extradural space. There was also some congestion of the vessels within the dura.

After the vertebrae had been split longitudinally, forcible flexion and extension produced no motion between the vertebral bodies at the site of the operation, and there was no change in length of the bodies of the operated vertebrae. Microscopic examination of a piece of tissue removed from the operative area showed osteoid tissue on the surface. Beneath the osteoid layer were bone trabeculae, with numerous marrow cells.

Dog D-2, Aged One and One-Half Years

Experiment 2 was begun on January 17, 1945; the duration was 146 days. At operation the disc between the fifth and sixth lumbar vertebrae was exposed through a mid-line abdominal incision. A portion of the disc was resected, and the remainder was curetted thoroughly. The disc itself was not very wide. A small metal marker was inserted into the area in which the operation had been performed. The wound was closed in layers in the usual manner.

At the end of 146 days the gross specimen showed complete bony bridging between the two bodies from which the disc had been removed at operation (Fig. 2). There was no movement between the bodies nor between the corresponding facets. There was a slight

tendency for a dorsal protrusion of bone toward the spinal canal in the operative region. The lateral roentgenogram showed osseous tissue, projecting into the spinal canal. The vertebrae were not split for study, but were kept as a gross specimen. There was a loss of four millimeters in length of the combined measurements of the two vertebrae from which the disc had been removed at operation.

FIG 3-A

Dog D-3. Resected disc, immediately after operation.

Dog D-3, Aged Four Months

Experiment 3 was started on January 23, 1945, and continued for 140 days. At operation the disc between the fifth and sixth lumbar vertebrae was exposed through a mid-line abdominal incision. The disc was partially excised with the scalpel, and the remainder was removed as thoroughly as possible with a curette. A marker was placed in the lower vertebra (Fig. 3-A).

The findings at the end of 140 days were as follows: After the vertebral column had been dissected out, there was complete osseous bridging across the area from which the disc had been excised (Figs. 3-B and 3-C). On flexion and extension there was no movement between the bodies, the corresponding articular facets, or the spinous processes. The specimen was split longitudinally and again there was found to be a complete bony bridge between the two bodies. There was an area of degeneration in the conus medullaris at this level, which may have been due to injury at the time of the operation. The roentgenogram showed complete bony bridging between the vertebrae which had been operated upon (Fig. 3-D). There was a slight tendency for bone proliferation into the spinal column, as seen in the lateral roentgenogram (Fig. 3-E). There was also some rounding of the bodies in this region. The fused bodies measured less than they did at the time of the operation. The adjoining vertebrae showed a definite increase in length. Some loss would be expected to result from removal of the disc tissue and some from injury to the epiphyseal plate, as this was a growing animal.

Dog D-4, Aged Four Months

Experiment 4 was started on January 23, 1945; the duration of the experiment was 140 days. At operation the disc between the fourth and fifth lumbar vertebrae was exposed through a mid-line abdominal incision. The disc was partially excised and was then thoroughly curetted. A marker was placed in the body of the proximal vertebra.

Upon exposing the operated area at the end of 140 days, there was found to be complete bony bridging between the two bodies from which the disc had been removed. There was no movement between the bodies. There was no motion between the articular facets, corresponding to the operated vertebrae. The articular cartilages of the facets appeared

FIG. 3-B

FIG. 3-C

Show complete bony bridging in the disc,—anteroposterior view (Fig. 3-B) and lateral view (Fig. 3-C).

a little thinner than normal. There was no movement of the spinous processes of the vertebrae which had been operated upon, although those outside of this area moved very freely. Upon opening the spinal canal, an enlargement of the cord at the site of the fused disc was seen. Considerable hemorrhagic exudate was observed along the anterior border of the canal; it extended along several vertebrae. An adhesion extended from the disc to the dura. Upon opening the dura, some engorgement of the blood vessels was noted.

The roentgenograms showed the fusion between the vertebrae at the site of operation. There was a loss in length of the fused vertebrae, and some dorsal convexity of the fused bodies of the vertebrae.

Dog D-5, Aged Four Months

Experiment 5, which was begun on January 31, 1945, was continued for forty-three days. At operation, through a lateral lumbar approach, the body of the second lumbar vertebra was exposed, after the transverse process had been removed with an osteotome. The disc between the second and third lumbar vertebrae was partially resected and then curetted.

At the end of forty-three days, a loss of tissue was observed between the two vertebrae. There was some motion between the bodies, but considerably less than normal. There was no evidence of new bone. The disc had been replaced by dense fibrous tissue.

FIG 3-D

FIG 3-E

Fig. 3-D Anteroposterior view, showing complete bony bridging with fusion of the bodies.
Fig 3-E Lateral view, showing fusion of the bodies, with a tendency for posterior projection of bone into the vertebral canal

No changes were found in the canal or about the cord The roentgenograms showed thinning of the disc.

On microscopic examination, there were heavy, dense trabeculae and osteoid tissue, similar to the callus seen in the healing of a fracture Some of the osteoid tissue looked like the young cartilage tissue found in the nucleus pulposus

Dog D-6, Full Grown

Experiment 6 was begun on January 31, 1945; the duration was 122 days. At operation, through a mid-line incision and transabdominal approach, the disc between the fourth and fifth lumbar vertebrae was exposed. The disc was incised and as much as possible was removed with the curette. A metal marker was placed in the proximal vertebra.

Upon exposing the operated disc on the abdominal surface at the end of 122 days, a mass of bone was seen on each lateral margin, connecting the two vertebrae. These masses were rounded and projected almost 0.5 centimeter. Between the two lateral sections of bone, there was some tissue of softer consistency The dura was exposed by removing the spinous processes and the laminae. There was some hemorrhage along the anterior surface of the spinal canal. The dura was adherent to the area of the dissected disc There were no changes within the dura.

The anteroposterior roentgenogram showed complete bony bridging on both lateral aspects of the vertebrae, with an area of diminished density between them. The lateral view showed osseous bridging on the anterior surface, with less dense tissue between the bodies of the vertebrae.

There was no increase or decrease of growth of the normal vertebrae or of the vertebrae which had been operated upon.

Microscopic examination revealed that the section from the lateral pieces of tissue was made up of an outer layer of bone, beneath which was osteoid tissue. Numerous marrow cells were in the spaces between the bone. The inner layer of tissue was composed of cartilage cells. The process was similar to that of a healing fracture in a long bone.

COMMENT

Complete bony bridging occurred between the bodies of the vertebrae of dogs after the intervertebral disc had been removed. The bone proliferation was more active in young animals.

When firm osseous union took place, the combined length of the two vertebrae which had been operated upon was less than before operation; when union was not completely osseous, there was no diminution in length. With bony union, buckling toward the spinal canal tended to occur, which might account for some loss of length. If a disc operation is performed upon a growing individual, one should take into consideration the possibility of retardation of growth, with resulting deformity of the spine.

In the removal of the disc from the abdominal side, there was evidence of injury to the dura and cord. Likewise, in the dorsal approach there is danger of injuring the large vessel on the abdominal side. Care should be taken to avoid such injuries.

After the intervertebral disc had been removed, there was no gross evidence of displacement of the articular facets.

Although none of the operations were performed by the dorsal spinal approach, it can be predicated from the results of these experiments that, in dogs, if the disc is thoroughly removed so as to expose the bone on either side, osseous union will take place between the two bodies. The method of union is similar to that observed in the healing of fracture in a long bone.

CONCLUSIONS

Complete osseous union took place in dogs between the bodies of the vertebrae, following removal of the intervertebral disc. In young animals the union was more rapid and more likely to be completely osseous.

Complete bony union between the bodies produced sufficient fixation to prevent movement between the articular facets and between the spinous processes. When union was incomplete, there was considerable fixation of bodies, but movement took place between the articular facets.

KNEE FUSION BY THE USE OF A THREE-FLANGED NAIL *

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In doing an arthrodesis of the knee for Charcot's disease in February 1943, it was found that stability could not be secured by the usual methods of fusion. The presence of degenerative changes with fragmentation necessitated such extensive resection before viable bone was exposed that the resulting joint had a gap of one and one-quarter inches, and the transplanted patella failed to stabilize the site of arthrodesis. The debrided knee surfaces were held together manually and a vitallium nail of the Smith-Petersen type was driven across the joint space after the tibial graft had been implanted. Excellent stability was achieved immediately. Recovery was accompanied by complete ankylosis (Fig. 1-C).

The same procedure has been used since that time to provide stability in cases where ankylosing operations were performed for Charcot's joints, arthritis, residual poliomyelitis, old suppurative arthritis, spastic hemiplegia of the aged with fixed flexion deformity, completely relaxed ligaments (hydrocephalus), and in those knees where the patella had previously been removed. The author has avoided it to date where tuberculosis was present; in one tuberculous knee, fused elsewhere by this method, amputation was necessary later. Secondary infection—which frequently occurs in conjunction with such lesions—spread along the nail tract, causing massive disorganization.

On the basis of clinical experience the author believes that, where indicated, this procedure is valuable; and hence it is being presented.

OPERATIVE PROCEDURE

The usual anterior horseshoe incision should be extended upward on the medial side to expose the upper portion of the medial femoral condyle (Fig. 2-A). The ligamentum patellae and the capsule are divided, and the synovial membrane is completely removed. The posterior two thirds of the patella is removed, and either discarded or used as a free graft. The cortex of the upper anterior portion of the tibial tuberosity is removed to expose cancellous bone for patellar contact. A section of the patellar ligament is removed, so that, after suture, the patella is drawn down into contact with both the tibia and the femur. Débridement of the joint, with removal of the cartilage from the femoral and tibial condyles, is done. The tibial spines and cruciate ligaments are excised. This leaves a larger surface of tibial plateau for contact with the flattened surface of the femoral condyle. The menisci are excised. In cases of Charcot's disease of the knee joints, the ends of the tibia and femur are cut away until viable bone is secured. Good apposition of the flat surfaces should be obtained, with the knee straight. At first the patella was transplanted, as in the Hibbs fusion technique. Now, flat surfaces of the femur and tibia are nailed, with no free graft interposed. The deep surface of the remainder of the patella acts as a viable graft across the joint. A vitallium nail of the Smith-Petersen type is driven from the upper surface of the medial femoral condyle downward through the condyle and through the tibial head and shaft (Figs. 2-B and 2-C). A screw has been placed obliquely through the patella into the tibia to hold the patella down and firmly apposed. Routine closure and dressing are carried out. A snug-fitting, long plaster boot is applied. After from ten days to three weeks the foot portion of the boot is removed; for the next three months only a cylinder cast is used. Occasionally the cast is removed and a long leg brace is applied. Except in cases of Charcot's joints, the patient may become ambulatory on crutches three weeks after operation.

* Read at the Orthopaedic Section of the Medical Society of the State of New York, New York City, May 1944; and at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 21, 1946.

REVIEW OF CASES

Arthrodesis of eighteen knees has been performed by this method since February 1943. In four of the cases it is less than three months since operation, and ankylosis has not yet been secured.

In two of three instances of Charcot's joint, the knees became solid. Three knees with infectious arthritis, two of which had previously had sinuses, have become ankylosed. Arthrodesis was completed successfully in five patients with osteo-arthritis; and in two patients, fusion was achieved for residual poliomyelitis with instability. One relaxed, unstable knee in a patient with severe hydrocephalus became ankylosed. Of the first fourteen cases, union was secured in all except one with a Charcot's joint and severe disintegration. This patient is now ambulatory, and weight-bearing is possible with the aid of a cane and a long leg brace.

Of the patients in whom union was secured, all support was removed and full weight-bearing was possible in from three to six months, except for one syphilitic patient with a

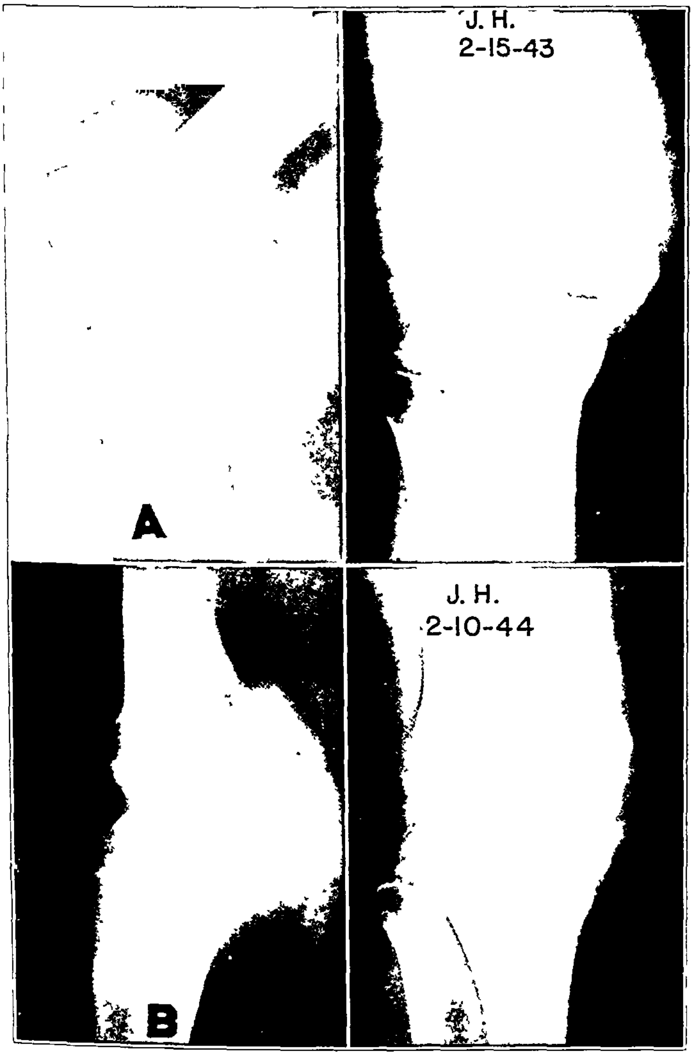

Fig. 1-A and Fig. 1-B

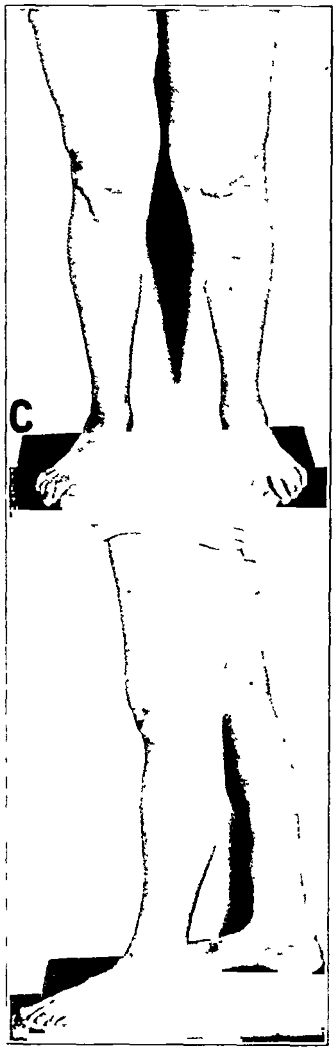

Fig. 1-C

Fig. 1-A: Charcot's disease of the knee, showing massive derangement.
Fig. 1-B: Fusion has been secured by the methods described.
Fig. 1-C: Weight-bearing is possible on the ankylosed knee after operation.

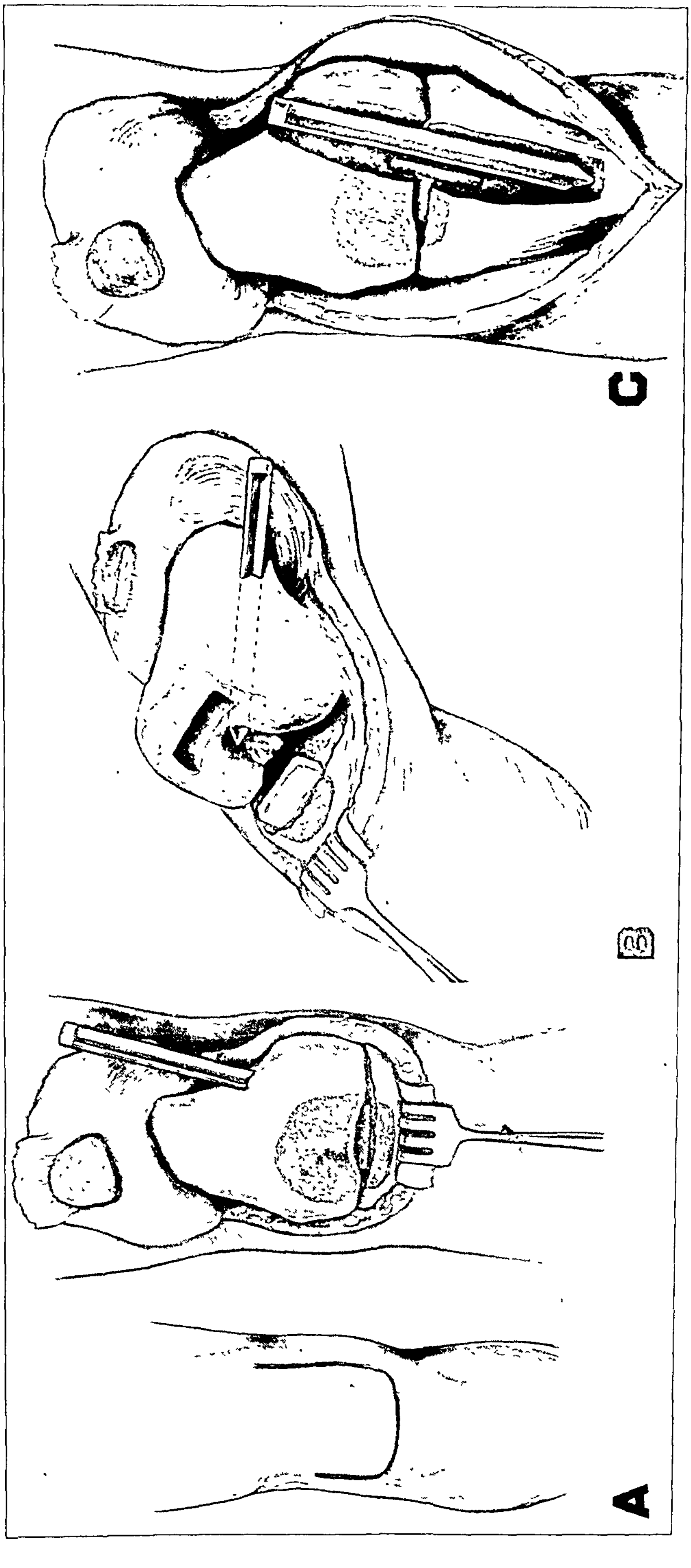

FIG. 2-A FIG. 2-B FIG. 2-C

Fig. 2-A: Inset shows horseshoe incision, extending upward on medial surface of knee joint to expose medial femoral condyle. There is good apposition of bone surfaces. Implantation of patellar graft is shown. Insertion of nail in medial femoral condyle is indicated.

Fig. 2-B: Knee is flexed to show position of the nail as it starts to traverse the joint space. Note that the upper surface of the tibial tuberosity is cut clean across; the spines of the tibia and the cruciate ligaments have been removed, giving a much wider area for ossification between the femur and tibia.

Fig. 2-C: Showing the position of the nail, fully driven into the femoral condyle and tibial head, traversing and stabilizing the joint space.

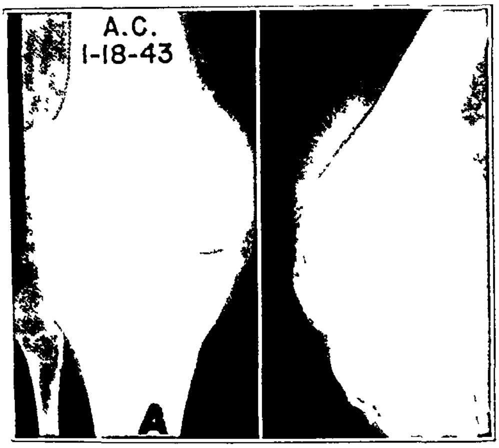

Fig. 3-A

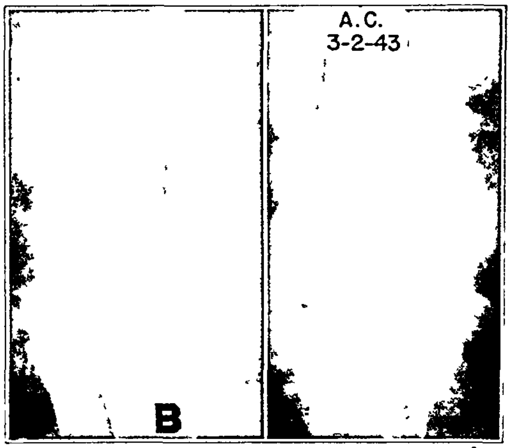

Fig. 3-B

Fig. 3-A: Knee of patient with poliomyelitis. Massive relaxation and a great deal of bone atrophy were present.

Fig. 3-B: Fusion achieved by method described, with separation of bone elements due to relaxation.

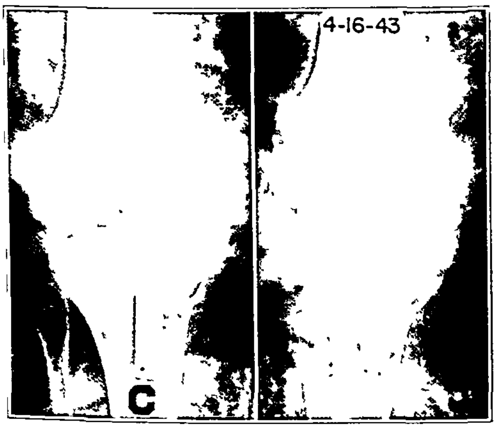

Fig. 3-C

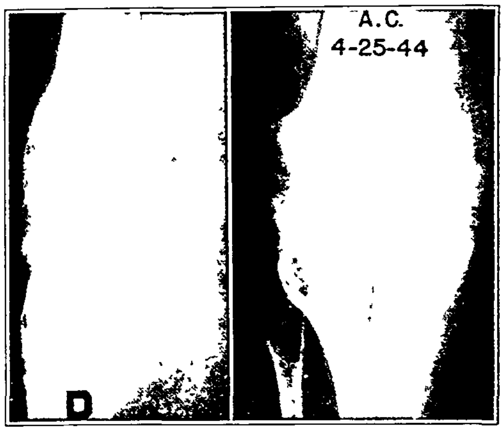

Fig 3-D

Fig. 3-C: Coaptation was secured by impaction through manual percussion on the heel

Fig. 3-D: Arthrodesis has been secured. Note action of patella, crossing the joint as a free graft Here, and in Fig. 1-B, a headless vitallium nail was used; in this instance the nail was inserted with the square end first. A nail with a head is now employed.

Charcot's joint. This patient had had an attempted knee fusion previously, which had failed. Union occurred with reoperation by the method described, and in this case a year elapsed before full weight-bearing could be undertaken. Hospitalization was necessary for from three to five weeks, except in the cases of Charcot's disease and in the patients who had poliomyelitis. The latter patients remained in the hospital for a longer period, because of other operative procedures. One other patient, who required hospitalization for two and a half months, had an unsuspected sensitivity to iodine, benzoin, adhesive tape, penicillin, and numerous other drugs. Her allergic manifestations were so severe as to cause her to be extremely uncomfortable for almost a month after operation.

No other postoperative complications were encountered, and there were no deaths. One patient suffered a gunshot wound of the femur four months after operation, without disturbing the fusion. All wounds healed primarily, except in one recent case; this patient has been found two months after operation, although afebrile, to have several sinuses through the incision line.

The nail has been removed in one case only. In this instance, the patient complained

of tenderness over the base of the nail. She was readmitted to the hospital, after complet ankylosis had occurred, and the nail was removed easily through a stab incision. Two o the patients had arthritic lesions in the other knee of less extent than those in the kne which was arthrodesed. Both of these patients have felt that their "good" knees wer improved after the weight-bearing facility provided by the ankylosed knee. Hip spicas o braces were not used; long leg splints were sufficient. A few thin headless nails were use at first, but ordinary four-inch hip nails of the Smith-Petersen type have been foun satisfactory.

This method has not been used where (1) tuberculosis was present, (2) where an ope epiphyseal line would have to be crossed by the nail, or (3) where osteomyelitis had bee present or suppurative arthritis was still active. In these instances, a Hibbs fusion o simple resection has been done. Where growth is almost complete, crossing the epiphysea plates with a nail is permissible.

This method of fusion offers the following advantages:

1. A long plaster boot only is necessary. The short, fat woman who needs knee fusion therefore presents a simple problem. By this technique the plaster hip spica, previously used, can be avoided.

2. The period of hospital care is shortened.

3. The devitalized free graft, which requires more time for complete ossification, may be dispensed with. In several of these cases the knees have become solid and fully weight-bearing within three months.

4. Not only is stability gained immediately; but the nail permits continued apposition of the bone surfaces, in case absorption or separation takes place before union has occurred. By early repeated manual impaction on the heel and, later, by partial weight-bearing with crutches, the tibia may be made to slide on the nail and to come into contact with the femur; but it cannot become displaced laterally, and union will occur (Figs. 3-A, 3-B, 3-C, and 3-D). The bone surfaces of relaxed knees (such as are seen in poliomyelitis) are also more easily kept in contact by this method.

DISCUSSION

Dr. Allen F. Voshell, Baltimore, Maryland: Dr. Bosworth has suggested a new and rather simple method of more closely apposing the surgically prepared surfaces of the femur and tibia, when fusing knee joints in adults suffering from Charcot's disease and its joint disintegration. Any procedure which will hold the two freshened bone surfaces close together until new bone tissue can bridge the space is advantageous. An obliquely placed nail; a loop of strong wire; staples, such as Blount uses in epiphysiolysis; or transfixed pins above and below are some of the satisfactory methods of stabilization. It would seem that a method allowing progressive "snugging up" of the surfaces might be better; but I was interested to note that, in the slides shown by Dr. Bosworth, there was no spreading apart of the bone ends and no degeneration about the pins or sliding of the pins. This seems to me to be the gauge of the efficiency of the method, provided fusion does occur.

The position of fixation shown is with the leg in full extension. This brings up the question of the better utility of some flexion; flexion allows greater comfort when sitting and still doesn't detract from stability.

By tradition, I would be opposed to the use of this procedure in tuberculosis, due to the effects upon the epiphyses and the trauma to good bone tissue nearby, with the possibility of spreading the disease. I shall be interested to hear further from Dr. Bosworth, after he has had more experience.

Dr. Edwin W. Ryerson, Chicago, Illinois: The use of the three-flanged nail in arthrodesis of the knee joint is an excellent procedure. It will prevent rotation and will afford good fixation.

In adults, I think the knee should be fused in about 15 degrees of flexion, as this position is more generally useful than full extension. Children's knees, however, should be perfectly straight, because even a few degrees of flexion will inevitably become exaggerated to a full 90 degrees in the course of time.

TREATMENT OF CONGENITAL DISLOCATION OF THE HIP *

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The most common cause of failure in the treatment of congenital dislocation of the hip, in children four years of age or younger, has been the discontinuance of immobilization before an adequate acetabulum has been formed by the pressure and function of a reduced and articulating femoral head. No good criteria have been described for determining when to discontinue cast or splint fixation after reduction of the dislocated hip. Some surgeons have recommended that the hip should be kept immobilized for five months; others recommend seven, nine, or twelve months, or longer. Most orthopaedic surgeons discontinue immobilization when the hip joint appears to be stable.

Many patients, after reduction of a congenitally dislocated hip and immobilization for varying periods of time, still have markedly inadequate acetabula, although the femoral heads may not become redislocated. An inadequate acetabulum will result in disability, and redislocation may occur later in life.

Poor end results in the treatment of congenital dislocation of the head of the femur will be much less common, if the reduced hip is held securely in the acetabulum until a thoroughly adequate hip joint can be demonstrated roentgenographically. To be acceptable, the hip must be relatively normal from the standpoint of depth and slope of the superior portion of the acetabulum, and the remodeling of the femoral head and acetabulum must be such that they fit accurately and articulate smoothly.

Surgeons are aware of the harmful effects of long periods of inactivity which may result from continuous immobilization in plaster, and this has influenced their decisions with respect to the time when all splinting should be discontinued. For several years the authors have used a modified Denis Browne splint as a part of the treatment of congenital dislocation of the hip. Rotation of the limb is under complete control, and a long bar between the two foot plates maintains wide abduction. With this as a convalescent splint, continuous pressure of the head of the femur in the acetabulum has been maintained, without rigid immobilization.

The deepening and molding of the hip joint after prolonged functional splinting conform to the law of functional adaptation described by Wolff, which states that every change in the form of a bone or of its function is followed by certain definite changes in its internal architecture and equally definite secondary alterations in its external form.

The orthodontists are able to reshape the bones of the jaw completely by means of very mild pressure applied to the teeth for prolonged periods. A similar principle holds with respect to the deepening and molding of the acetabulum and reshaping of the head of the femur. In either instance, however, a period of many months or even of years may be necessary in order to obtain a completely satisfactory end result.

Every experienced orthopaedic surgeon has observed the development of a secondary acetabulum in the ilium, above the unused acetabulum, in cases of old unreduced congenital dislocation. The forces which produced the secondary acetabulum are multiplied by use of the spreader splint to remodel the true acetabulum. Hourglass constrictions of the capsule of the hip joint will be dilated, or fat and fibrous tissue in the acetabulum will be compressed until absorbed, if this same molding pressure is maintained for a long enough time after the dislocation has been reduced.

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

When the abduction splint is used, atrophy of disuse—either of muscles or of bones—is minimum, because the extremity may be exercised while the contact and pressure of the femoral head are maintained in the acetabulum. The movement of the hip in the acetabulum helps to reshape the articulation and to make a more normally functioning joint than is possible from the static pressure obtained in a "frog-leg" cast or a plaster hip spica (Fig. 1). The abduction splint permits flexion and extension in the hip joints. Patients may sit up and some of them have even managed to walk. When stability of the hip permits, the splint may be removed daily for bathing and, as the acetabulum deepens, for longer periods of activity. Perhaps its greatest usefulness is as a convalescent splint, which may be worn at night for two or more years, while unrestricted walking and all activity are permitted throughout each day.

FIG. 1

Spreader cast which is worn until the hip appears to be sufficiently stable to make it safe for the use of the removable convalescent splint.

Attempts have been made to subdivide congenital dislocations of the hip into several groups, depending upon the period of development in which the dislocation originated. However, many embryologists, anatomists, and orthopaedic surgeons are unwilling to accept such theoretical divisions as foetal, natal, or postnatal dislocations. Although there are various degrees of acetabular dysplasia, with varying positions of the head of the femur in its relationship to the acetabulum, most cases are hereditary in origin. As Stewart has aptly stated: "The pathology of congenital deformities is sown in heredity, develops in embryo, and fruits under the trade winds of use". The differentiation of the hip joint is completed in the ninth week of foetal life, and the adequacy of the articulation has been determined before that.

Detailed anatomical dissections of the hip joints and surrounding tissues of a girl, aged seven years, who died three months after manipulative reduction of congenitally dislocated hips, were made by Allison in 1905. From these dissections and from observations made during clinical studies, Allison concluded that the basis of the pathology was as follows:

1. A poorly developed acetabular cavity.
2. An underdeveloped and irregularly shaped femoral head.
3. An abnormal direction of the neck of the femur.
4. Shortening of the adductor group of muscles. (These muscles were found to have been injured by the forced manipulative reduction, both in the muscle elements and in the nerve supply to the muscles.)
5. Shortening of the posterior muscles, the fascia lata, the iliotibial band, the iliofemoral band, and of all pelvitrochanteric muscles.

A completely satisfactory result of treatment of a congenitally dislocated hip should include correction of each of these abnormal conditions.

Twenty-three years later, Allison reported a clinical study of marked pathological changes which developed over a period of years in congenitally dislocated hip joints, although the dislocations had been reduced during infancy or early childhood and the reduc-

tions had been maintained. He decided that the degenerative arthritic changes were caused by the persistently inadequate depth and abnormal shape of the acetabula. The patients had been treated by cast immobilization long enough to prevent redislocation, but not sufficiently long to permit the acetabulum and the head of the femur to become accurately adapted to each other. Allison thought also that much permanent deformity resulted from the use of force in the reduction of congenital dislocations.

Ghormley has reported hypertrophic arthritis of the hip, which occurred in adult life, in a series of patients whose hip joints were congenitally inadequate. The arthritis occurred in these subluxated hips regardless of whether they were congenitally deficient, or remained inadequate after the reduction of congenital dislocations because treatment had been discontinued too early.

Neither Allison nor Ghormley supplied the answer to the problem which they described. Only rigid fixation was being used in the earlier years. The objections of Allison to prolonging rigid fixation beyond the time when the reduction could be maintained without it are now obviated by a splint, which permits motion in the hip joints while still maintaining position.

The purpose of this presentation is to re-emphasize the value of movement and function, as well as of prolonged positional splinting, in the development of a completely satisfactory hip joint after reduction of a congenital dislocation. The plan of treatment described here has been used by the authors for three years. Sixteen patients have been so treated. Of these, two had bilateral dislocations. The youngest patient was five months old at the time of beginning treatment, and the oldest was just over three years of age. The use of a removable abduction night splint, which permits motion in the hip joint, was described by one of the authors.[4]

No statistical analysis or end-result study can be made until these patients are several years older. The authors' observations, however, support the conclusions of Ponseti. He described a similar method of management of congenital dislocation of the hip, and stated that a satisfactory development of the hip joint could be obtained by prolonged abduction splinting without immobilization.

CASE REPORTS

The following cases, observed by the authors, illustrate the application of this method of treatment:

CASE 1. S.B., a girl, aged one year, had congenital dislocation of the right hip. In July 1943 the dislocation was reduced by gentle manipulation, under general anaesthesia. A "frog-leg" cast was applied to maintain 90 degrees of abduction. Three months later this position was changed to 45 degrees of abduction and slight internal rotation of the right lower extremity, maintained by a single hip spica cast.

In January 1944 the cast immobilization was discontinued, and a Denis Browne splint with a long spreader bar was applied. In February the patient was trying to stand while wearing the splint and fell, suffering a greenstick fracture of the right femur. A hip spica cast was reapplied. In March the cast was removed, and the right hip was found to be subluxated. The spreader splint was reapplied, with immediate reduction of the dislocation.

Approximately one year from the date of beginning treatment the hip was completely stable; the spreader splint was then removed for one hour each day. The splint-free time was increased an hour every week. By October 1944 the patient was given complete freedom of activity throughout each day, but splints were worn at night. In December the patient walked or ran without any limp. The roentgenograms, however, showed the hip joint to be shallow, with a sloping acetabular roof. The night splints were continued.

In December 1945, two and one-half years after the initial reduction, the right hip was normal from the standpoint of function, and completely satisfactory roentgenographically. Torsion of the femur had been corrected. However, since the night splinting did not interfere in the least with the comfort or rest of this patient, it was planned to continue it for at least six more months.

CASE 2. A.W., a girl, aged one year, had congenital dislocation of the right hip. In February 1944 manipulative reduction was carried out, and a cast was applied to maintain the lower extremities in

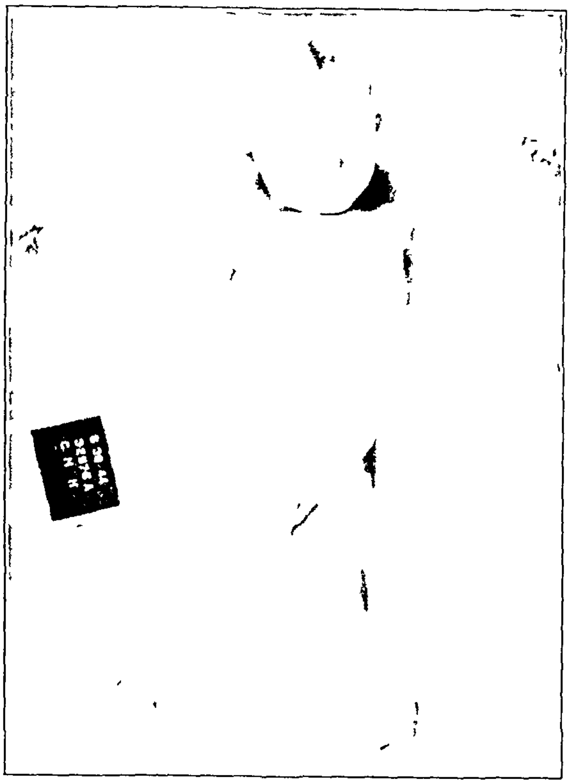

FIG. 2-A

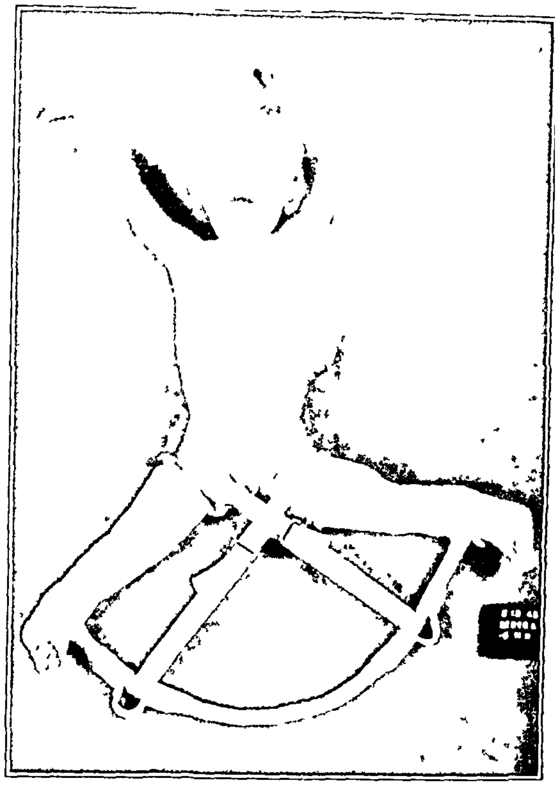

FIG. 2-B

Case 4 (L.F.)

Fig. 2-A: Arthrogryposis with congenital dislocation of hips, bilateral congenital dislocation of knee, and bilateral talipes equinovarus.

Fig. 2-B: Method used for reducing, without undue force, hips which were held almost rigid by surrounding fibrous tissue. Note pressure pads applied against trochanters.

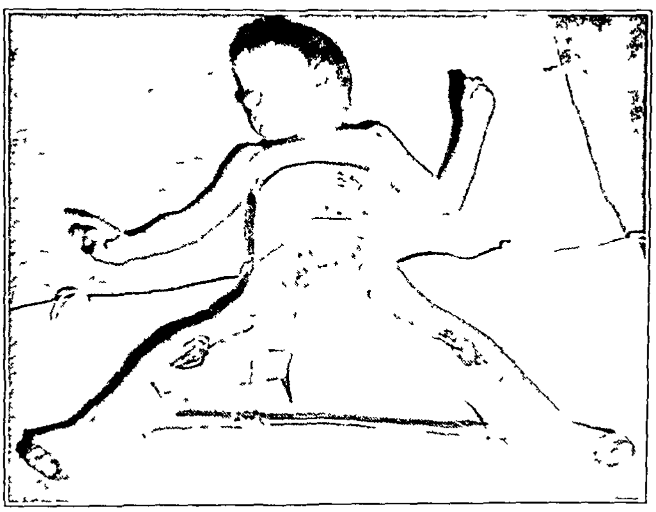

FIG. 2-C

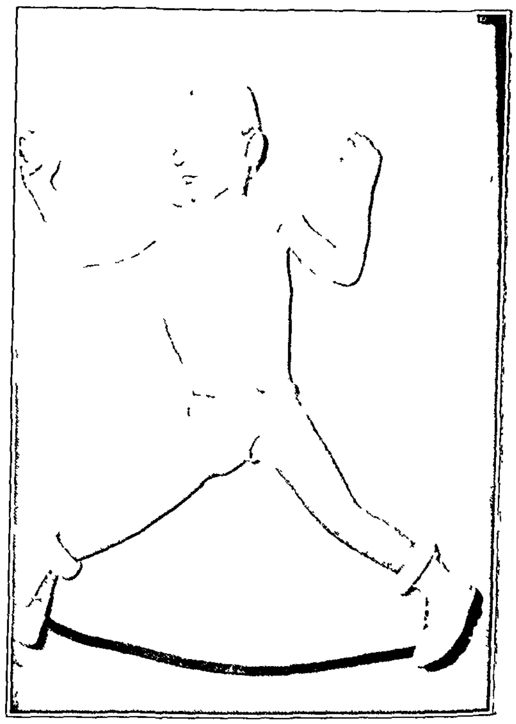

FIG. 2-D

Fig. 2-C: *Position 2* Wide abduction with only moderate internal rotation for maintaining reduction of both hips.

Fig. 2-D: Convalescent splint which may be removed for bathing; later it will be worn only at night. Splint will not be discontinued for two or three years, or until roentgenograms show a thoroughly adequate acetabulum and smoothly articulating femoral head for each hip.

90 degrees of abduction. In August a Denis Browne splint with a spreader bar was applied. Three months later, reduction was secure. Splints were discontinued during the day, but applied at bedtime.

By October 1945 function was completely normal. Roentgenograms revealed a well-developed acetabulum, although the capital femoral epiphysis showed some retardation of development.

CASE 3. R.H., a boy, aged eight months, had dislocation of the right hip. Preliminary stretching

of unusually short and tight adductor muscles was instituted for ten weeks by means of bilateral toe-to-groin casts, maintained in progressively increased abduction by a long spreader bar.

In December 1941 the dislocation was reduced successfully by manipulation. A "frog-leg" cast was applied. Three months later, this was replaced by an abduction hip spica.

FIG 2-E

Roentgenogram of congenital dislocation in connection with arthrogryposis, showing the high displacement after treatment was started.

FIG 2-F

Twelve months after reduction; the position is being maintained in long spreader convalescent splints. Note slight flattening of ossification center of femoral epiphyses. Acetabulum, however, is beginning to deepen. Splints will be continued until the articulation is completely satisfactory.

In September 1945, a Denis Browne splint with an abduction bar was applied. On examination in December 1945, the reduction had been maintained and the acetabulum was developing satisfactorily. It was decided to begin leaving the splint off during part of each day. A night splint was to be continued for at least one more year.

CASE 4. This patient had arthrogryposis, with bilateral dislocation of hips and knees and talipes equinovarus deformities. The dislocations were very difficult to reduce, since motion of all joints of the lower extremities was restricted by extensive fibrosis. A preliminary period of abduction and traction made it possible to accomplish the reduction without undue force. Spreader splints now maintain reduction of the dislocation in the hips and correction of the club-foot deformities, and at the same time permit exercise of hips, knees, and ankle joints (Figs. 2-A to 2-F).

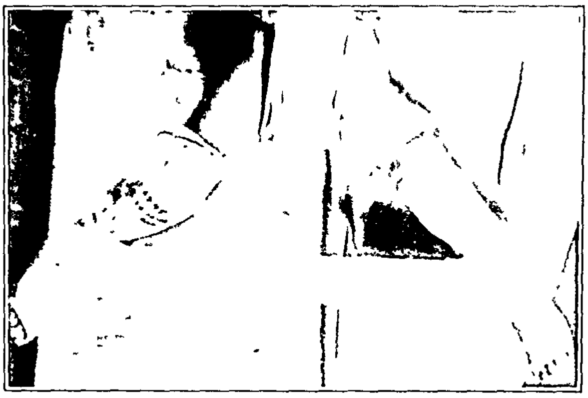

FIG. 3

Abduction casts, which are extended onto the thigh to relieve some of the strain on the knee. This type of fixation replaces the abduction spica cast of the body and lower extremities.

Many different types of splint have been used in attempts to obtain reduction without forceful manipulation and to maintain reduction without the prolonged use of plaster casts, which immobilize both the hip joint and one or both lower extremities. Putti devised and used an abduction splint, consisting of two boards that were padded and hinged together at one end. He was successful in obtaining reduction of dislocations of the hips in children, whom he treated during the first few months of life by gradually increasing abduction of the lower extremities. After the reduction had been maintained for two or three months, the splint was replaced by a wedge-shaped cushion covered with waterproof cloth. This program of treatment was continued for from eight to twelve months.

FIG. 4-A

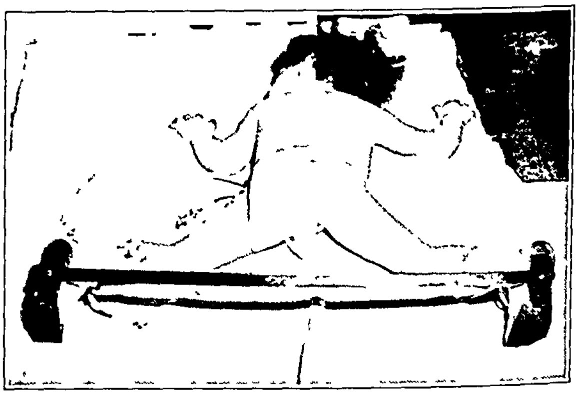

FIG. 4-B

Removable convalescent splint applied about six months after the initial reduction. May be removed for bathing and later left off for increasing periods each day, provided the reduction of the hips remains stable, as shown by examination and roentgenograms. After about two months, it is left off all day, but should be continued as a night splint for an indefinite period of time,—probably not less than two years.

Ridlon, who was also a keen observer, recognized the primary defect of malformation of the acetabulum, and the secondary fact of maldevelopment of both the acetabulum and the head of the femur, because of the lack of functional stimulus in the dislocated hip. Coonse described a modification and improvement of the Putti splint and later, together with Stewart, reported a series of cases which were treated successfully by this method. Jaeger used a wide abduction splint and added a pressure pad over the trochanter to aid in deepening the acetabulum. Freiberg incorporated turnbuckles in plaster casts which had been applied bilaterally from the mid-thigh down to and including the foot. By this

means he was able to increase abduction until the heads of the femora were reduced into the acetabula.

The importance of movement and function in the growth of the infant and of the development of the muscles and bones of the limbs was recognized by Galland. He advocated the use of bilateral spica casts which extended only to the knees; motion of the ankles and knee joints was permitted, while the thighs were held in a position of complete abduction.

Schwartz recently reported the successful treatment of a case of bilateral congenital

FIG 5-A
Roentgenogram of bilateral dislocation of the hips before treatment

FIG 5-B
Roentgenogram taken twelve months after the initial reduction The acetabula have developed satisfactorily, and there is no evidence of damage to the heads of the femora The spreader night splint is still worn and will be continued for at least one more year, although this patient is ambulatory and has no limp.

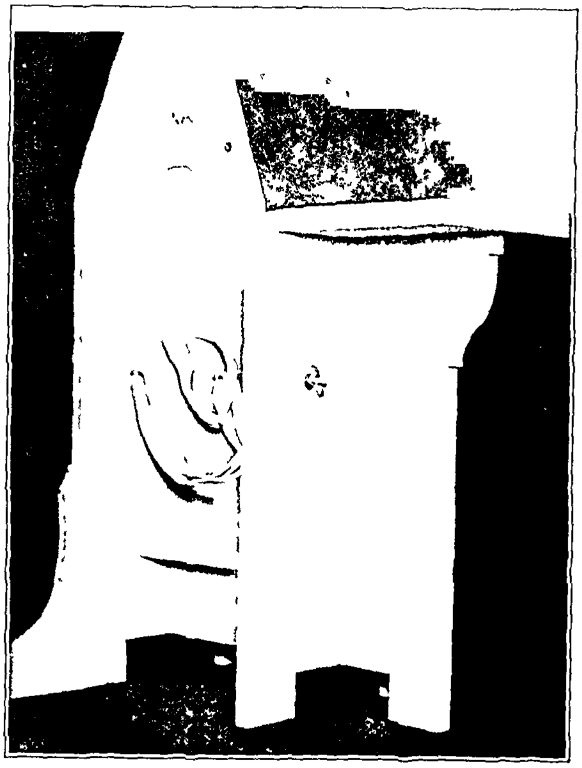

FIG. 6-A

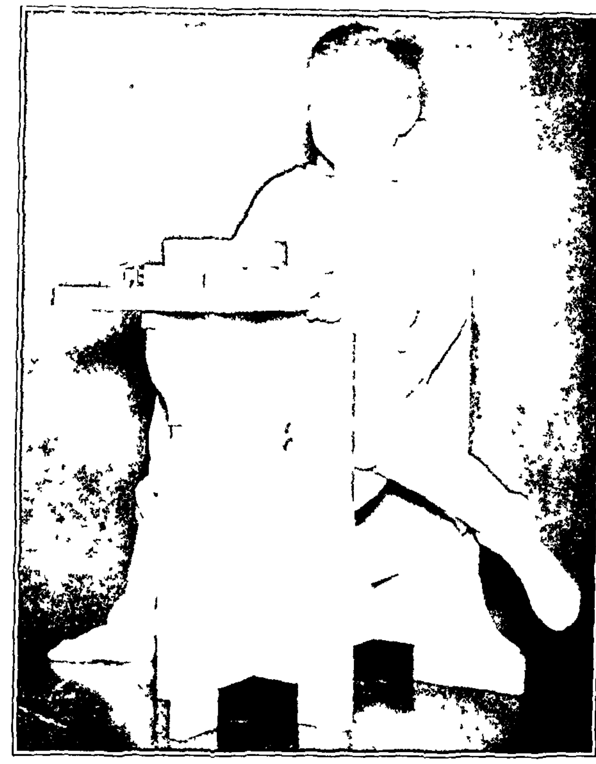

FIG. 6-B

The type of chair used at Children's Memorial Hospital for children in the "frog-leg" or abduction plaster casts.

dislocation of the hip by means of a spreader cast, applied only to the lower extremities, with the knees flexed 90 degrees and with the addition of a V-shaped plaster instead of a straight crossbar. This maintained a position of 90 degrees of abduction, but still permitted the patient to sit up. Thus, Schwartz also recognized the importance of freedom of rotation of the pelvis on the fixed femoral head in the more rapid development of the acetabulum.

Although the authors were not informed of his work, Ponseti, in the clinic of Dr. Arthur Steindler, began using a removable spreader splint and plan of treatment almost identical with ours. The authors have no desire to try to establish priority with regard to any part of the principle which has been discussed. They are sufficiently enthusiastic about the advantages of this program of care to urge others to try it.

The plan of care which the authors have adopted as a routine is as follows:

Position 1: The lower extremities are maintained in the "frog-leg" cast, in 90 degrees of abduction, for two months.

Position 2: An abduction spica cast is maintained for two months (Fig. 2-C).

Position 3-A: Bilateral casts of the lower extremity, held widely apart by means of a plaster strut to maintain constant abduction and slight internal rotation, are used for two months. This type of cast has the advantage of permitting the patient to sit up and to be reasonably active. It cannot be removed by an unwise parent at the risk of redislocating the hip (Fig. 3).

Position 3-B: A Denis Browne splint with a long spreader bar is worn for two months, but removed each day for the bath (Figs. 4-A and 4-B). The hip should be stable, but will still reveal a shallow acetabulum.

Position 3-C: The spreader splint is left off for one hour, morning and afternoon, but is worn for the remaining twenty-two hours each day. Each week an additional hour of freedom from the splint is added, until it is finally left off during all of each day. The splint should be reapplied at bedtime each night, until the hip joint appears to be normal,—both

from the standpoint of function and roentgenographically. The night splint should not be discontinued until roentgenograms show an approximately normal hip joint with good depth, normal slope to the roof of the acetabulum, and a well-formed and well-rounded head of the femur. The torsion of the femur will be corrected, in most cases, without the necessity of an osteotomy (Figs. 5-A and 5-B).

Experience with this method has encouraged the authors to express the opinion that most congenital dislocations of the hip can be reduced, the reduction maintained, and a relatively normal hip joint—from the anatomical and functional standpoints—developed by means of prolonged functional splinting. Patience and perseverance on the part of the surgeon will be rewarded by reduction without trauma, and by stability of the hip without loss of function and without pain and disability from osteo-arthritis and subsequent deformity. When treatment can be started before the patient is four years of age, open reduction should not be necessary. Regardless of age of the patient or method of obtaining the reduction, the long abduction splint should be used at night for as many years as may be necessary in order to obtain a completely adequate acetabulum and smoothly articulating femoral head.

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DISCUSSION

DR. H. R. MCCARROLL, ST. LOUIS, MISSOURI: This principle in the management of congenital dislocation of the hip has been attempted in many varied ways. It has at times been used in an attempt to accomplish the reduction itself, but for this it has never been very successful. Its use, as described by Dr. Compere, is, in my estimation, not so simple or so perfect as his paper would lead us to believe. There are five points which I wish to stress:

1. The "frog-leg" position employed as Step No. 1 is, I believe, unnecessary. The initial fixation could as well be one of internal rotation and abduction.

2. Dr. Compere apparently uses a preliminary manipulation for reduction of the hip. Changes taking place in the femoral heads of patients so treated in past years have been due to damage, resulting from the manipulation; and to a pressure necrosis, resulting from the tremendous force of the capital epiphysis against the acetabulum. This was Dr. Crego's primary reason for the institution of preliminary skeletal traction in these patients. Dr. Compere's patients, whose dislocations have been manually reduced and whose hips have been fixed in abduction for many months, can reasonably be expected to show similar changes a few years from now. Force exerted against these femoral heads is a more important factor than an inadequate acetabulum in the development of these early degenerative changes.

3. Dr. Compere states that a fold of capsule or fibrous tissue in the acetabulum will disappear if this treatment is continued long enough. He fails to mention that an occasional case is encountered in which the acetabulum is so completely filled with fibrous tissue that reduction is utterly impossible until the tissue has been removed. The principle he describes cannot work unless the head has been reduced.

4. Dr. Compere speaks of congenital dislocation of the hip as though all dislocations are identical. I still believe that there are three distinct primary types of congenital dislocation. Most of our difficulty is encountered in the treatment of the primary anterior type. A position of abduction and internal rotation cannot and will not prevent the head from slipping forward through the defect in the anterior rim of the acetabulum. This we know, because we have tried it in repeated instances. In this type and even in some of the posterior dislocations, some form of reconstruction of the acetabulum will be required, regardless of how long fixation is continued.

5. If femoral torsion, as stated, can be corrected by this prolonged fixation, this represents its principal advantage. However, to accomplish this, the patients are immobilized for approximately one year. By derotational osteotomy, this time can be appreciably diminished. This would seem preferable to me, especially in our clinics, where many patients must travel great distances, and must stay in the hospital until treatment has been completed.

While this principle has a place among our therapeutic measures, unfortunately the treatment of congenital dislocation of the hip is not simple and cannot be covered in generalities, as intimated. Each patient presents an individual problem. We occasionally see a hip which becomes redislocated after treatment has been completed. Fixation for a few months by the method described, which permits mobility of the hip, will frequently ensure permanent stability. To me, this represents its principal value. For this, however, short-leg plaster casts and a crossbar serve the purpose very well. This type of fixation was described by Badgley, in his Presidential Address before this Academy in 1943.

Dr. Edwin W. Ryerson, Chicago, Illinois: Several important points have been emphasized in this excellent paper. If all congential dislocations of the hip could be recognized and reduced during the first twelve or fourteen months, the results would be far better than can be achieved in older children. The right-angle "frog" position should be maintained until a competent acetabular rim can be demonstrated by roentgenogram. In bilateral dislocations, the Denis Browne splint will provide excellent abduction after the removal of the plaster-of-Paris spica, and will afford, as Dr. Compere has said, enough freedom of motion to stimulate the development of the joint. It facilitates cleanliness and ease of handling. I have never used it, because for many years I have found that a light, waterproof spica of cellulose acetate is comfortable and efficient.

In unilateral cases, the spica is bivalved and hinged, and the child learns rapidly to walk with a high sole on the normal side. In bilateral cases, the cast is bivalved and held by straps and buckles, as no hinges can be used, and it is astonishing to see how well such children can handle themselves and how comfortably they can sit on chairs and even walk.

I described this method in 1926, in *The Journal of Bone and Joint Surgery,* after using it for more than ten years; but, so far as I know, nobody else has ever tried it.

COMPOUND COMMINUTED FRACTURES INVOLVING THE ELBOW JOINT

Treatment by Resection of the Fragments *

BY J. T. NICHOLSON

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Observations of battle casualties have revealed that, when compound comminuted fractures involving the elbow joint are treated by resection of the fragments, a stiff, painful elbow with draining sinuses is avoided, and a useful elbow results. The frequent complications of suppurative arthritis and osteomyelitis are aborted. The patient remains ambulatory and his evacuation can be carried out under conditions allowing minimum care. The wounds about the elbow heal rapidly, and early function can be permitted. Unless the fracture is associated with a nerve lesion, no especial after-care is required, and thus the period of hospitalization is reduced.

HISTORICAL BACKGROUND

Resection of the elbow joint has been practised for almost two centuries. According to Ashhurst, a resection of the lower end of the humerus was done by Wainman and by Tyre in 1758 or 1759, and a complete resection of the elbow joint was performed by the elder Moreau in 1794. Park, in 1783, described the surgical approach through a single longitudinal incision parallel with the radial border of the ulna.

Resection after gunshot wounds of the elbow, with compound comminuted fractures involving the joint, was employed extensively during the numerous European wars of the early Nineteenth Century. This is revealed in Table I, which was prepared by Otis. The high mortality from the procedure, 44.5 per cent., was due to inability to control shock and infection, rather than to lack of surgical skill. This is apparent in a report by Burke of an excision of a soldier's elbow joint in the Regimental Field Hospital in Crimea in 1855. The wound was brought together by means of sutures and adhesive plaster; this was followed by extensive swelling. Two sutures were removed and "very copious and exhausting suppuration succeeded". Mr. Burke was "disposed to attribute the supervention of the unpleasant symptoms above mentioned to a constitutional diathesis ill adapted for the receipt of the shock of a severe wound, such as is frequently observed in soldiers after a certain term of military service".

In the American Civil War, Otis reports the results of 626 cases of elbow resection. There was a mortality rate of 23.7 per cent., which was about half the mortality rate of the series reported for the preceding fifty years. The mortality rate during the Civil War from amputation of the upper arm was 23.6 per cent. The lowest mortality observed by Otis (Table II) occurred in the delayed or secondary resection. He stated that the high mortality rate in the intermediary resections was due to the frequent incidence of septicaemic infections and hemorrhage. He pointed out that primary resection was preferable, as the source of infection was attacked and the period of convalescence was shortened. This, he declared, had been emphasized by Esmarch, Langenbeck, and Stromeyer. He claimed excellent results "when the joint ends of either the upper or forearm have been removed after complete exposure of the joint, and the uninjured portions of the articulation have been unmolested".

Fifty years later, in World War I, among the reports of elbow resections reviewed,

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

TABLE I

SHOWING THE RESULTS OF CASES OF SHOT FRACTURE OF THE ELBOW TREATED BY EXCISION ON THE OCCASIONS NAMED AND FROM THE AUTHORITIES QUOTED *

Action, etc.	Total	Recovery	Deaths	Result Unknown	Percentage of Fatality
Revolution in Paris, 1848 (Baudens)	2	1	1	..	50.0
War in Sleswick-Holstein, 1848–50 (Esmarch)	40	34	6	..	15.0
Crimean War, Russian (Hubbenet)	25	7	9	9	56.2
Crimean War, French (Chenu)	4	..	4	..	100.0
Crimean War, British (Matthew)	20	17	3	..	15.0
Italian War, 1859–60 (Demme, Rodolfi)	3	3	..	..	0.0
New Zealand War, 1863–65 (Mouat)	1	1	..	..	0.0
Danish War, 1864 (Loeffler)	43	30	13	..	30.2
Six Weeks' War, 1866 (Beck, Stromeyer, K. Fischer, Maas, Haschek, Berend)	53	43	10	..	18.8
Campaign in Dalmatia, 1869 (Riedl and Ebner)	2	2	..	..	0.0
Franco-German War, 1870–71 (Barthelmess and Merkel, Beck, Bergmann, Billroth, G. Fischer, H. Fischer, Goltdammer, Graf, Herrgott, Kirchner, Koch, Langenbeck, Lossen, Lücke, MacCormac, Mayer, Ott, Rupprecht, Schaeffer, Schinzinger, Schüller, Socin, Steinberg, Stoll)	183	135	48	..	26.2
Franco-German War, 1870–71, French (Chenu)	212	48	164	..	77.3
Aggregates	588	321	258	9	44.5

* *Taken from* Otis[5], p. 901.

four pertinent observations were outstanding. First, there were no reported mortalities. This was attributed to the prevalent use of Dakin's irrigation and of gauze packing in the wounds. Second, while primary or secondary resections were usually favored, Swan contended that there was no additional risk in intermediate resections. This he attributed to his use of mixed polyvalent streptococcus and proteus vaccine in all cases. Third, although it was universally conceded that the wounds be left open after excision, Shepherd advocated partial closure of less severe wounds and complete closure of the early wounds, after they had been excised and "bipped" [treated with bismuth iodoform paraffin paste]. Fourth, there was more conservatism in the amount of bone excised. Moore stated that the functional result was inversely proportional to the amount of bone removed.

These progressive measures of twenty-five years ago were practically taken for granted in the care of the compound comminuted fractures of the elbow joint which comprise the material for this presentation. The author adopted this method of treating compound comminuted fractures of the elbow joint after observing, over a ten-year period, a

TABLE II

NUMERICAL STATEMENT OF SIX HUNDRED AND TWENTY-SIX CASES OF COMPLETE OR PARTIAL EXCISIONS OF THE BONES OF THE ELBOW JOINT FOR SHOT INJURY †

Operations	Total Cases	Recoveries	Fatal Cases	Result Unknown	Mortality Rate, Determined Cases
Primary	322	250	68	4	21.3
Intermediary	197	127	69	1	35.2
Secondary	54	49	5	..	9.2
Time of operation unknown	53	44	4	5	8.3
Aggregates	626	470	146	10	23.7

† *Taken from* Otis[5], p. 845.

patient of Willard's who had had his elbow blown out with a dynamite charge; and after examining several patients of Buzby's who had had resection, rather than arthroplasty, for ankylosis of the elbow joint.

CLINICAL MATERIAL

During the campaign in the Solomon Islands in 1942, a few patients with extensive compound fractures of the elbow, with marked comminution of the joint surfaces of the humerus, ulna, and radius, were treated from three to ten days after injury by resection of the fragments. Impressive were the subsidence of fever, relief of pain, and diminution of drainage. Unfortunately, no follow-up examinations could be planned for these patients, as they were evacuated from island to island, by ship or plane, until they reached the United States. In the past two years it has been possible to observe twelve patients with compound fractures involving the elbow joint, caused by bullet or shrapnel wounds, in whom the bone fragments were removed from two to six months after injury. Suppurative arthritis with draining wounds existed at the time of operation in every case except Case 2. The patients have been followed from one to seventeen months after operation.

TECHNIQUE

The patient was given a general anaesthetic. The apparatus supporting the elbow was removed, and sterile gauze was placed over the wounds. The entire arm, from finger tips to axilla, was scrubbed with a hand brush and green soap. The hair was shaved. The skin was prepared with ether, alcohol, and merthiolate. A pneumatic cuff, inflated to 212 millimeters of mercury, was used as a tourniquet. A lateral approach to the elbow joint was used. Only the loose fragments of bone were removed; and no resection of intact bone, other than the radial head, was undertaken. The cartilage which covered the bone ends was not removed. In those patients in whom the trochlea was not fragmented, a pannus usually covered most of the cartilaginous surface. Beneath the pannus, the cartilage had lost its normal luster and whiteness; but it was not removed. All granulations and purulent material in the area were swabbed and flushed out as well as possible. Only those metallic particles which were in the field of operation were removed.

The operative incision was closed primarily, except in two patients, where it extended into large granulating wounds. When small wounds lay in the line of incision, they were excised and closed with the incision. No attempt was made to close the second wound or sinus communicating with the elbow. A compression dressing from the finger tips was applied before the tourniquet was released.

In the early cases, a plaster-of-Paris cylinder, extending from fingers to axilla, was believed necessary for immobilization. It was found, however, that the patients were not uncomfortable after the fracture fragments had been removed, so that a simple anterior splint was used for only two weeks. This was followed by a sling. The patient was encouraged to take his arm out of the sling and to discontinue its use entirely after the fourth week. After from four to six weeks, the men went on convalescent leave. During this time, considerable progress in motion was made in every case.

TREATMENT

Sulfonamides were used in the early cases treated on shipboard. Powdered sulfathiazole was sprayed into the wound, and the tablets were given orally. When penicillin became available, the patient was given 20,000 units every two hours for twenty-four hours before operation and for seventy-two hours after operation. Penicillin was given by continuous hypodermoclysis after operation in one case. No particular change was observed in the patient's postoperative course, and psychologically he was very unhappy about the necessity of remaining in bed for three days.

COURSE

Signs of infection in every case cleared rapidly after operation. No patient had a postoperative fever. There were no secondary hemorrhages. When the first dressing was

Fig 1-A

Fig 1-B

Case 7. Photographs showing the underlying wound, fifty-one days after injury.

Fig 1-C

Roentgenograms reveal the extent of comminution of the bones of the elbow joint

Fig. 1-D

The appearance of the bone ends is shown, 135 days after resection of the fragments.

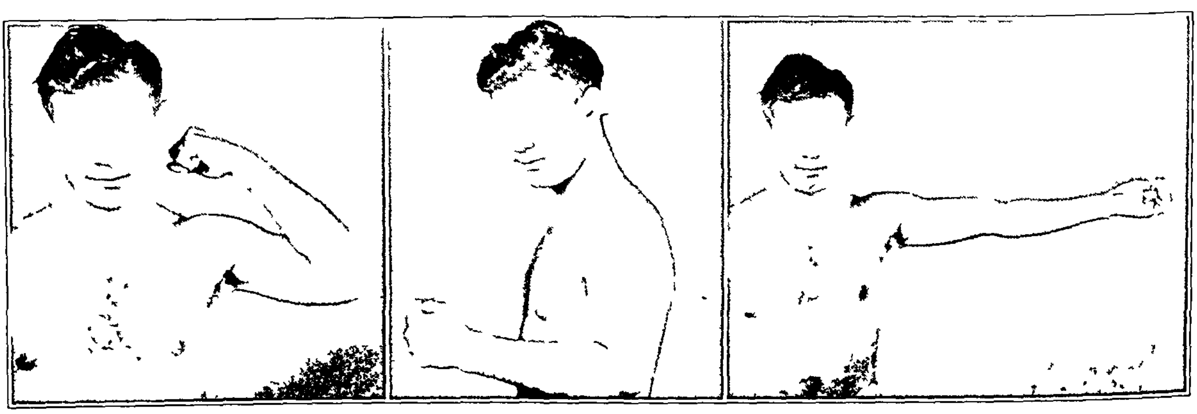

Fig. 1-E

Photographs indicate the range of elbow motion.

done at two weeks, the wounds were crusted to the dressing. When the dressing had been removed, there was no free drainage from the open wounds or sinuses. The elbow had lost the fusiform swelling and had practically regained its normal contour. The absence of pain was noted. Some of the patients recalled the discomfort they had had when the supporting cast was removed before operation to permit photographs, and they were amazed to move their elbows without pain through a range of from 20 to 30 degrees.

COMPLICATIONS

The complicating injuries included third-degree burns, wounds of the chest, and fractures of the other extremities. The local complicating injury was damage to the radial or ulnar nerve. An injury to the median nerve did not occur in this series of cases. The radial and ulnar nerves were both paralyzed in one patient, but recovery took place spontaneously over a period of six months after the injury. The ulnar nerve alone was involved in four patients; in one, recovery was spontaneous. The radial nerve alone was involved in one patient; there was spontaneous partial recovery. The nerves which failed to recover were explored by members of the Peripheral Nerve Service, and were found to have lost continuity. These nerves were repaired, but sufficient time had not elapsed to report upon the extent of their recovery. No patient suffered an additional nerve injury as a result of the operative resection of the fragments of the elbow joint. A sinus persisted after operation in only one case; after three months, a sequestrum was re-

FIG. 2-A

Case 3. Photograph taken fifty-six days after injury.

FIG. 2-B

Roentgenograms show the appearance of the elbow after resection of the capitellum and head of the radius.

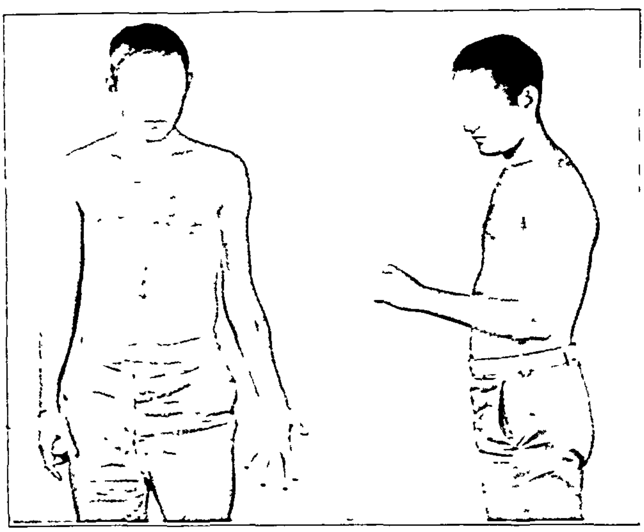

FIG 2-C

Patient illustrates elbow motion, 113 days after operation

Fig. 3-A

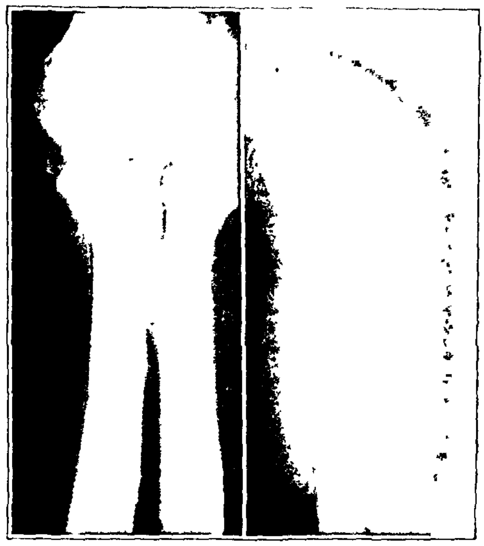

Fig. 3-B

Case 4. Roentgenograms show the shattered olecranon seventy-six days after injury (Fig. 3-A) and after resection (Fig. 3-B).

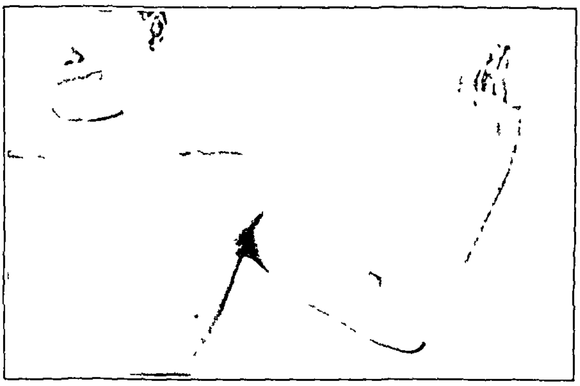

Fig. 3-C

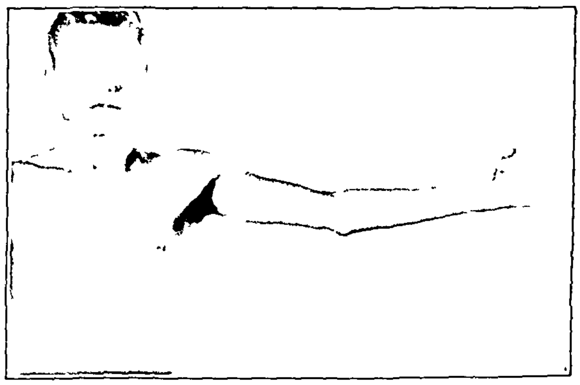

Fig. 3-D

Elbow motion 127 days after operation is shown.

moved. Healing was primary, and no further drainage occurred during four months of additional observation. In three cases the head of the radius was removed within from three to six months after resection to improve active pronation. In these cases there was no joint space, but dense fibrous scar tissue was present between the bone ends. The roentgenographic examination of the resected joints, four or more months after operation, frequently revealed spicule formation about the bone ends. No loss of motion had been observed as a result of these bone changes.

ANALYSIS OF RESULTS

The condition of the injured elbows remained almost stationary until the underlying fragments had been resected. There was little wound repair. A wound, fifty-one days after injury, is shown in Figures 1-A and 1-B. Sixty-six days after resection of the fragments, the wound was completely healed. The regression of infection and the ability to attain function of the elbow were essentially the same, whether the resection was done in the primary, intermediate, or secondary phase. A resection in the primary stage, unless the injury was complicated by a nerve lesion, resulted in a much shorter convalescence. Resection and primary closure of the surgical wound, without regard for phase of injury, was possible with the use of penicillin.

The most important consideration in analysis of the results was the future function of the arm. This was found to depend upon the amount of bone resected (Table III). There were five classes of resection:

1. *Resection of Capitellum and Head of Radius* (*Three Cases*)

In Case 3 (Figs. 2-A to 2-C) the wound was resected and closed at operation; primary healing resulted. The fragments were resected an average of seventy days after injury in this group. The follow-up, which was made at an average of sixty-seven days, revealed lateral stability in extension or flexion; a flexion deformity of from 10 to 20 degrees; flexion against resistance to more than a right angle; no interference with the power of extension; and a relatively good range of supination and pronation.

2. *Resection of the Olecranon*

Case 4 (Figs. 3-A to 3-D) was the only case in this group. The fragments were resected and the ulnar nerve was transplanted seventy-six days after injury. The follow-up at 120 days revealed 10 degrees of lateral instability when the muscles were relaxed, no flexion deformity, and flexion against resistance to more than a right angle. Extension of the forearm against gravity was possible only to 20 degrees; but the arm could be abducted with the elbow in extension, and a fourteen-pound weight could be raised five inches above the head. The range of both supination and pronation was within 30 degrees of normal, although the head of the radius was not resected.

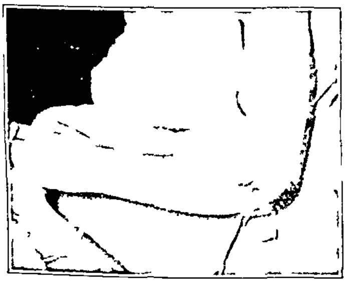

FIG 4-A

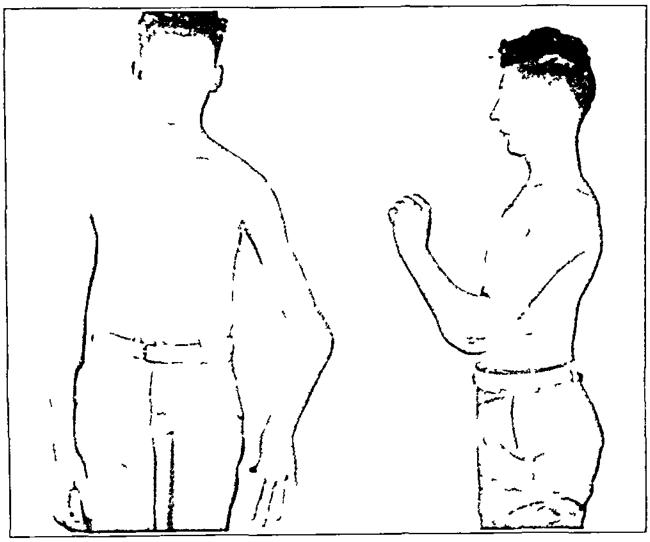

FIG 4-B

Fig 4-A Case 5 Condition of wound forty-five days after injury The wound was resected and closed at operation Primary healing took place

Fig 4-B Patient demonstrates range of motion fifty-five days after operation

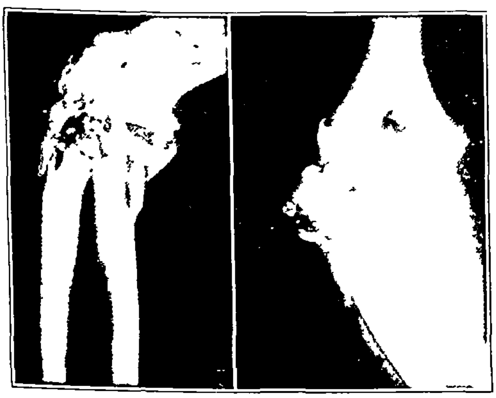

FIG 4-C

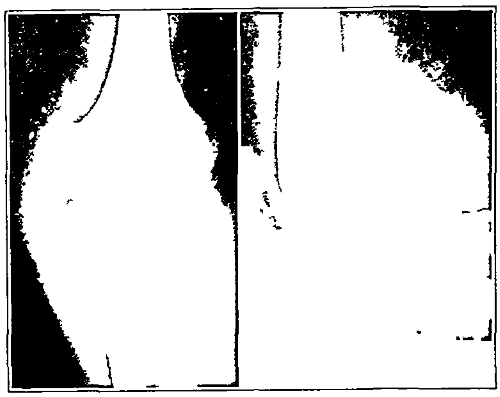

FIG 4-D

Fig 4-C. Roentgenographic appearance of elbow forty-five days after injury

Fig. 4-D. Roentgenograms taken 127 days after the resection

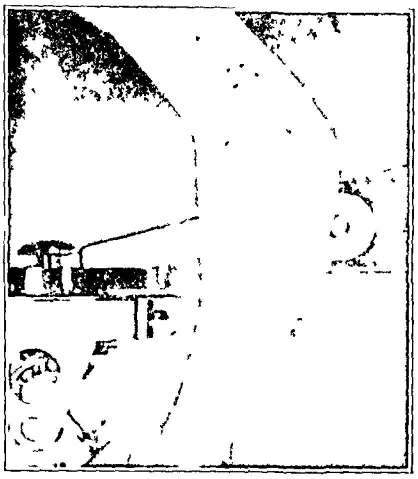

FIG. 5-A

Case 9. Photograph taken seventy-one days after injury. The elbow has a draining sinus and requires support.

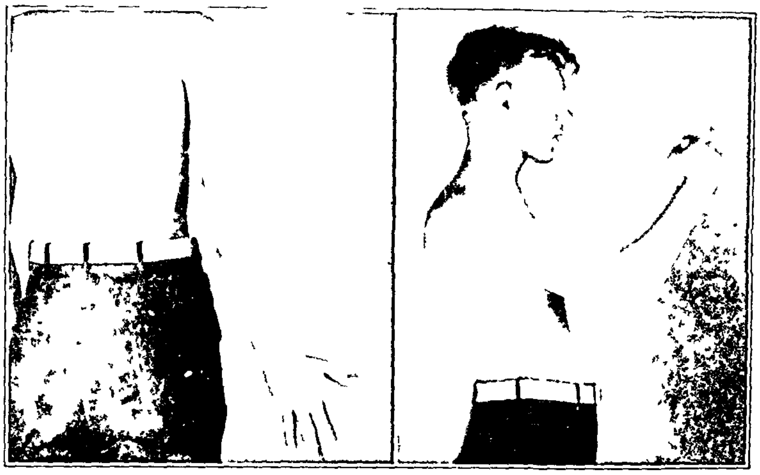

FIG. 5-B

Patient demonstrates range of motion fifty-eight days after operation.

FIG. 5-C

Before operation.

FIG 5-D

After resection.

3. *Resection of the Proximal End of the Ulna and Radius*

The one patient in this group (Case 5) had complete ulnar paralysis (Figs. 4-A to 4-D). The fragments were resected forty-five days after injury. The follow-up at 127 days revealed 25 degrees of lateral instability when the muscles were relaxed, a flexion deformity of 15 degrees, and flexion against light resistance to 90 degrees. Extension of the forearm against gravity was possible to 30 degrees. The arm could be abducted with the elbow in extension. Supination was possible to 30 degrees, and pronation to 10 degrees.

4. *Resection of the Condyles of the Humerus and the Head of the Radius*

There were three cases in this group. In two cases the fragments were resected not quite two months after injury, but in one patient (Case 8) resection was done six months after injury. A partial radial paralysis existed in Case 8. The patient also had a persistent sinus after operation, and on the 114th day a sequestrum was removed. The wound was still closed after four additional months. The most extensive wound was present in Case 7 (Figs. 1-A to 1-E); it was healed sixty-six days after operation. The head of the radius and the overlying scar were resected secondarily on the 126th day after operation, with resultant improvement in supination and pronation.

TABLE III

POSTOPERATIVE FUNCTION

Operative Resection	Case	Days After Operation	Days After Injury	Range of Flexion (Degrees)	Supination (Degrees)	Pronation (Degrees)	Abduction with Elbow Extended (Degrees)	Elevation with Elbow Extended (Degrees)	Extension against Gravity (Degrees)
Capitellum and head of radius	1, R.W.A.	60	125	160 to 30	90	90	90	90	90
	2, R.L.H.	30	120	170 to 30	90	60	90	90	90
	3. R.A.W.	113	169	160 to 80	60	20	90	90	90
Olecranon	4. W.A.B.	120	196	180 to 70	75	60	90	0	20
Proximal end of ulna and radius	5. R.F.C.	127	172	175 to 90	30	10	90	0	30
Condyles of humerus and head of radius	6, F.R.C.	90	169	205 to 30	90	20	90	0	25
	7, J.A.B.	135	186	190 to 30	65	0	90	0	10
	8. R.C.F.	248	445	190 to 80	10	20	60	0	25
Condyles of humerus, olecranon, and head of radius	9, H.E.G.	58	139	185 to 30	10	0	90	0	5
	10, J.R.W.	120	237	180 to 90	65	– 10	0	0	10
	11, L.A.K.	277	279	190 to 30	45	0	0	0	20
	12, C.B.	510	539	190 to 70	70	20	0	0	30

The follow-up of this group was made at an average of 200 days, and revealed from 30 to 45 degrees of lateral instability; no flexion deformity; but from 10 to 25 degrees of hyperextension. With five pounds of resistance, flexion was possible to more than a right angle; extension of the forearm against gravity was possible from 10 to 25 degrees, and the arm could be abducted with the elbow extended.

5. *Resection of the Condyles of the Humerus, the Olecranon, and the Head of the Radius*

There were four cases in this group. Case 11 was one of ulnar paralysis. A primary resection had been done. The patient's arm was flail until after a secondary resection of the head of the radius and the overlying scar had been performed on the 215th day. His improvement, as shown in Table III, was remarkable. In Case 12 a resection of the fragments was carried out on the twenty-ninth day. Although the patient was seen after injury, his complicating chest wound, hemorrhage, and shock did not permit immediate operation upon the elbow. He had a partial residual ulnar paralysis from his brachial wound. Because of a two-inch gap between the bone ends, a supination deformity, and lateral instability of almost 90 degrees in either direction, removal of the head of the radius and construction of lateral ligaments and expansion of the triceps with fascia lata were done on the 198th day after operation. In Case 10 a resection was performed on the 117th day after injury. The patient had a large granulating wound, three inches in diameter, over the medial surface; and a partial ulnar paralysis. The head of the radius was not removed at the time of operation, and a supination deformity resulted. In Case 9 (Figs. 5-A to 5-D) a resection was done eighty-one days after injury.

The follow-up of these patients, averaging 239 days after resection, revealed as much as 60 degrees of lateral instability; hyperextension against gravity of 10 degrees; and flexion against the resistance of a glass of water to 90 degrees or more. The initiation of this flexion was accomplished by eliminating the force of gravity. Extension of the forearm against gravity was from 5 to 30 degrees. Only in Case 9 could the arm be abducted

with the elbow extended. Pronation was possible to 20 degrees in one case. All of the patients had active motion at the distal humeroradial joint.

SUMMARY

Surgical resection of the fragments following a compound comminuted fracture involving the elbow joint was without major complications. The procedure was carried out in the presence of open draining wounds, in the primary, intermediate, or secondary phase of the injury. The patient was ambulatory from the first day after operation. Elbow motion was started after two weeks, and no mechanical support other than a sling was used.

The operative wound was closed primarily when penicillin was used. The temperature, pain, fusiform swelling, and drainage subsided after the resection. The operative wound healed primarily within two weeks. The healing time of the wound of injury depended upon the extent of soft-tissue damage.

The functional result was better when there was little loss of bone substance. If the trochlear surfaces of the humerus and ulna had been preserved, the elbow joint to all intents and purposes functioned normally. With the loss of the olecranon or the condyles of the humerus, the power of extension was sacrificed. The loss of the trochlear surface of the ulna added lateral instability in relaxation and slight loss of flexion power. The loss of the condyles of the humerus, alone or in conjunction with the proximal portions of the ulna and radius, resulted in about the same degree of additional loss in power of flexion against resistance and in further instability of the joint. Lateral instability of more than 45 degrees resulted in loss of ability to abduct the extended arm. Resection of two or three inches of the humerus resulted in a longer period before the power of flexion was regained, and in the most unstable joints. Even with a plastic repair, three inches was considered the greatest resection possible. The ability actively to supinate and pronate the forearm was, with one exception, dependent upon the absence of the head of the radius. Three patients were improved by a secondary operative removal of the head of the radius. The only patient who had a supination deformity failed to have the head of the radius removed. In all cases, pronation was more difficult to obtain than supination. A joint space did not reform at the site of the resected elbow, but fibrous scar tissue persisted between the bone ends six months after operation. Following operation, the formation of bone spicules at the bone ends was observed, but this had not resulted in loss of function.

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DISCUSSION

Dr Jean Verbrugge, Antwerp, Belgium I subscribe without hesitation to the main ideas contained in Dr Nicholson's paper, and congratulate him on his interesting historical data I had the opportunity and the privilege of observing some of his excellent results, at the United States Naval Hospital in Oakland

The main principle underlying the treatment of war injuries to the elbow lies in the well-known and widely accepted principle of débridement It is commonly recognized that débridement should be performed thoroughly at the level of the injured muscles and fascia, it is also known that one should be more parsimonious with the amount of skin resected But what about the bones?

When the injury is at the level of a diaphysis, every effort should be made to preserve as many fragments as possible, even at the risk of replacing the fragments of bone in their original position after curettage, whenever possible

When the injury affects a joint, however, especially in the upper extremity and still more especially the elbow joint, where ankylosis takes place so easily and interferes with function bone may and often should be resected more freely As Dr Nicholson says it will bring about faster healing and result in a shortened period of treatment and in a quick and better restoration of function

I would not fear as much as Dr Nicholson does resection of the lower end of the humerus Of course cases differ very much from one another but I would be tempted to divide them into two groups (1) those in which only one bone has been touched and the joint itself is fairly well preserved, and (2) those in which the fracture is comminuted and involves several bones and the joint space In the first group, I would resect the injured fragments as Dr Nicholson does, and suggest if the operation is performed very early, a thorough cleaning of the wound and cauterization of the raw surfaces of bone avoiding suture of the fascia, so as to prevent calcification In the second group, I would not hesitate to resort to the classic resection of the elbow including the lower end of the humerus

This prompts me to make the following comments

1 The name of Ollier should be mentioned in connection with resection of the elbow His incision "*en bayonette*" gives an excellent approach to the joint

2 Subperiosteal resection should be employed, because this technique will prevent hemorrhage, and will respect, as much as possible, the attachments of the muscles and the capsule

3 Use of scraping instruments like a sharp periosteal elevator or a curette should be avoided as much as possible

4 The head of the radius should be excised only if it has been damaged, in that case its excision is imperative

5 Immobilization by a plaster cast first, and a bivalved cast later, should be prolonged for many weeks and up to three months The period of immobilization depends upon the extensiveness of the resection and the condition of the periarticular structures

6 I cannot share Dr Nicholson's assurance about intermediate operation, when infection is present The danger of hemorrhage is then prevalent, the bone is thin, the veins are phlebitic, and the soft tissues often are diseased War surgery, however is often a matter of opportunism and judgment

7 From observing the late results it is often surprising to note how much strength and useful power can be secured in an unstable elbow, when it is flexed beyond the right angle Its aesthetic appearance may not be satisfactory, but it undoubtedly surpasses in value a stiff joint

Dr Nicholson mentions the conclusions arrived at after World War I His paper and the experiences of other military surgeons in World War II prove that the methods of treatment of compound comminuted fractures of the elbow will have to be revised

THE TREATMENT OF CHRONIC OSTEOMYELITIS BY THE USE OF MUSCLE TRANSPLANT OR ILIAC GRAFT

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The purpose of this paper is to present the method used in treating sixty-four separate foci of chronic osteomyelitis in sixty-one patients during the past sixteen months. Practically all areas of the skeleton have been affected (Fig. 1), including four cases which involved major joints with suppurative arthritis. Healing occurred in a high percentage of cases within ten weeks, and there have been no recurrences, pathological fractures, or fatalities. The average period of observation has been seven and one-half months. All patients were males between eighteen and thirty-seven years of age. The disease was due to the usual causes, being hematogenous in four (Cases 13, 14, 15, and 38 in Group A), secondary to operative infection in six (Cases 21, 26, 27, 28, 39, and 40 in Group A), and secondary to infected compound fractures (from falls, vehicular accidents, or gunshot wounds) in the remainder. The chronic granulomata of bone are not included in this series, although this method should be applicable in selected cases of this type of chronic bone infection.

The management of chronic pyogenic osteomyelitis has always been highly unsatisfactory, and is one of the most distressing problems in the field of orthopaedic surgery. Whether it is secondary to infected compound fractures or to the catastrophe of operative infection, or whether it is hematogenous in origin, the bone infection has been difficult to eradicate. Too often it results in crippling from stiffened joints, atrophied muscles, recurrence of the disease, pathological fractures, and occasionally from delayed union or nonunion of infected fractures. The chronic sepsis enforces an interminable delay in undertaking reconstructive surgery. Frequently, it is the direct cause of secondary anaemia and the rare, but serious, complication of amyloid degeneration. Nephrolithiasis is not an uncommon finding in these debilitated patients, particularly when prolonged recumbency is necessarily enforced. If there is a lesion of a peripheral nerve, associated with a compound fracture—as is frequently seen, due to the perforating, high-speed missiles of modern warfare—it is imperative to clear up infection early, in order that definitive neurosurgical procedures may be accomplished without delay. The longer the time interval between laceration of nerve tissue and surgical repair, the poorer is the prognosis for recovery of the paralyzed muscle groups.

The advent of the bacteriostatic drugs, particularly penicillin, at first gave promise of a possible cure. However, it soon became apparent that penicillin, like the sulfonamides, would not be effective, either systemically or locally, in tissues with little or no vascularity. Such tissues include sinus tracts with the surrounding cuff of dense scar tissue, bone abscesses containing chronically infected granulation tissue (which in the process of healing will become dense scar tissue), sequestra, and the area of eburnated bone which is frequently found at sites of chronic osteomyelitis. Furthermore, the newer bacteriostatic drugs, such as streptomycin, could hardly be expected to accomplish better results after chronic bone infection has become established. The value of these drugs as adjuvants to the surgical treatment of osteomyelitis is considerable, however, since more radical surgery is possible without danger of the localized infection becoming disseminated or assuming an invasive character. In all of the cases reported here, penicillin only was used, as it is less toxic than the sulfonamides. Streptomycin was not available for trial. In most instances (Table II) some bacterial species present were not sensitive to penicillin. How-

ever, penicillin was used systemically and locally, as it was felt that, if the usual invasive pathogens could be controlled by the bacteriostatic agent, the remaining organisms would be eliminated by the resistance of the host.

In view of these considerations, it was clear that some method of excision of all infected and potentially infected (hypovascular) tissue, which would result in prompt and complete healing with little or no chance of recurrence, was vitally necessary. This would allow early reconstructive surgery, including correction of deformity, bone graft, tenoplasty, and repair of lesions of the peripheral nerves and vascular lesions. Restoration of function would be greatly accelerated. The complications and sequelae mentioned would be reduced markedly, and the tremendous economic loss which chronic osteomyelitis has always exacted in the past would be curtailed.

Since healing depends to a great extent upon good vascularity of the tissues to be healed, it seemed apparent that simply removing sequestra and curetting the walls of the bone abscesses and sinus tracts would lead in too many instances to incomplete healing, subsequent breakdown, and recurrent drainage. If a radical excision of all avascular and infected tissue could be accomplished, however, and if the dead space so formed could be obliterated and the wound closed, then all the factors for prompt healing would be present. The rate of recurrence should be exceedingly small with such meticulous removal of all tissue which could act as a reservoir of potential infection. This very situation has long been noted in osteomyelitis of the ribs and fibulae. In these areas, excision of that portion of the bone containing the infection is almost invariably followed by prompt healing. This is due to the fact that, once the section of bone containing the diseased focus has been removed, the adjacent viable and vascular (and consequently infection-resistant) muscles fold into the defect, obliterating the dead space, and healing takes place.

The crux of the entire situation—the success or failure of a quick method of permanently healing a focus of

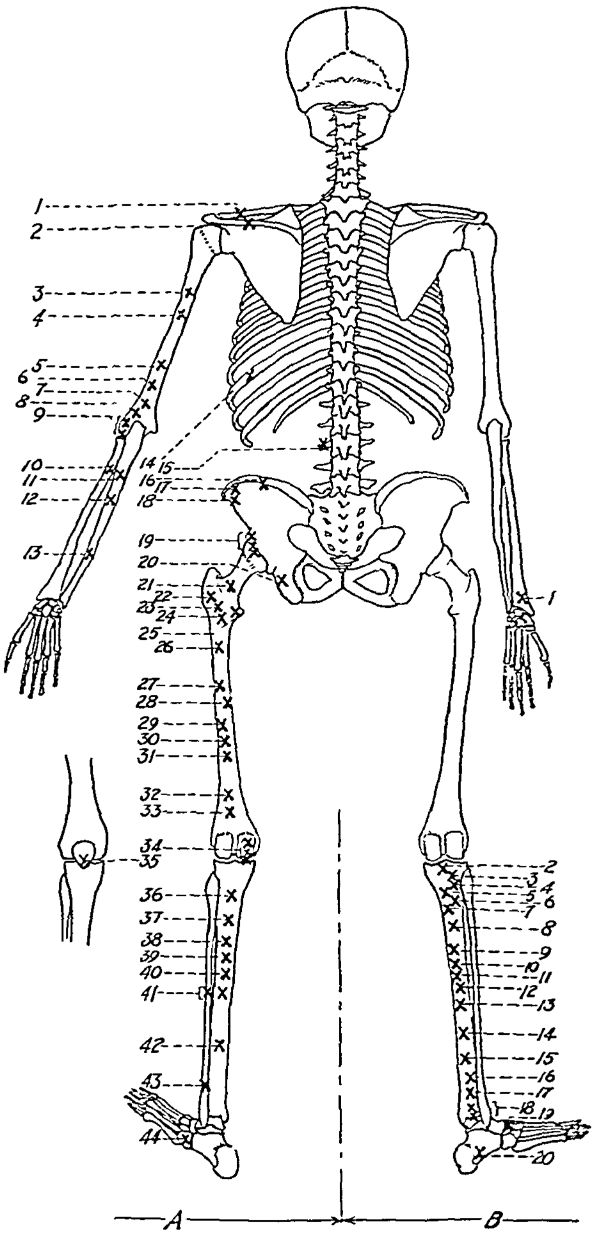


Fig. 1

Fig. 1: Distribution of chronic osteomyelitis in the sixty-four instances reported Numbers used for the cases in the text are based on this diagram.

A: The areas on the left (Group *A*) show the skeletal level of all foci which were treated by excision and obliteration of the defect with viable muscle.

B: The areas on the right (Group *B*) show the skeletal level of all foci which were treated by excision and filling of the defect with cancellous iliac bone.

TABLE I

The Incidence of Bones Involved in This Series *

	Number of Bones Involved	Per Cent.
Tibia	24	36.4
Femur	15	22.7
Humerus	7	10.6
Radius or ulna	5	7.6
Pelvis	5	7.6
Tarsals	3	4.6
Shoulder girdle	2	3.0
Ribs and transverse processes of vertebrae	2	3.0
Fibula	2	3.0
Patella	1	1.5
Totals	66	100.0

* The apparent numerical discrepancy is due to the fact that both the tibia and fibula were involved in Case *A*-41, and both the ilium and the head of the femur in Case *A*-19.

chronic osteomyelitis—therefore depends upon the successful obliteration of the dead space, as well as upon the complete excision of the diseased tissues.

OBLITERATING THE DEFECT WITH MUSCLE

For the past several years, principally since the advent of the sulfonamides, complete excision of foci of chronic osteomyelitis, with either partial or complete closure, has been recommended in the treatment of this disease. More recently, obliterating such bone defects by exteriorization (skin grafts applied directly to the defect) has again been advocated, and good results have been reported. However, radical excision of diseased tissue; filling any deep, rigid-walled bone defect by a viable muscle pedicle, as suggested by Starr and Mercer; and closure of the wound appear to be a logical approach to this problem. Consequently, it was decided that such a procedure would be the method of choice in treating chronic osteomyelitis of any area of the skeleton, provided that, surrounding the bone focus, there was sufficient muscle tissue which could safely be utilized to fill the defect adequately. Such skeletal areas would include the scapula, clavicle, humerus, forearm bones (except the radial styloid), and metacarpals in the upper extremity; the pelvis, femur, fibula, and metatarsals (and, in selected instances, the tibia), in the lower extremity; and the vertebral processes and ribs. In these areas the procedure has been to radically excise the avascular and infected tissue, fill the bone defect by viable muscle, and do a loose primary or secondary suture, even if this meant leaving the extremity flail, but clean surgically. In a few pertinent instances, this has allowed early repair of associated

TABLE II

Micro-Organisms Recovered from the Wounds in Twenty Cases of Compound Fracture Complicated by Chronic Osteomyelitis *

	Cases	Per Cent.
Pseudomonas aeruginosa (*Bacillus pyocyaneus*)	14	70
Staphylococcus aureus	10	50
Staphylococcus albus (facultative anaerobe)	8	40
Staphylococcus aureus (hemolytic)	7	35
Escherichia coli and paracolon species	6	30
Proteus species	6	30
Diphtheroids	3	15
Aerobacter aerogenes	3	15
Streptococcus viridans	3	15
Streptococcus pyogenes (*Streptococcus haemolyticus*)	3	15
Streptococcus species (non-hemolytic)	2	10

* With one exception, all wounds contained multiple species.

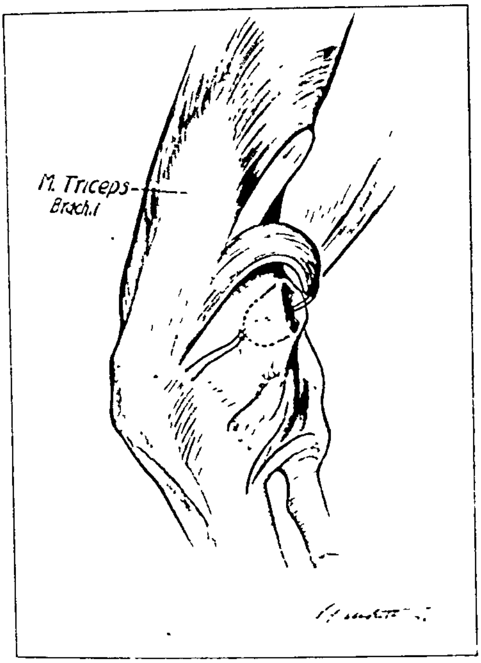


Fig. 2-A
Case A-8

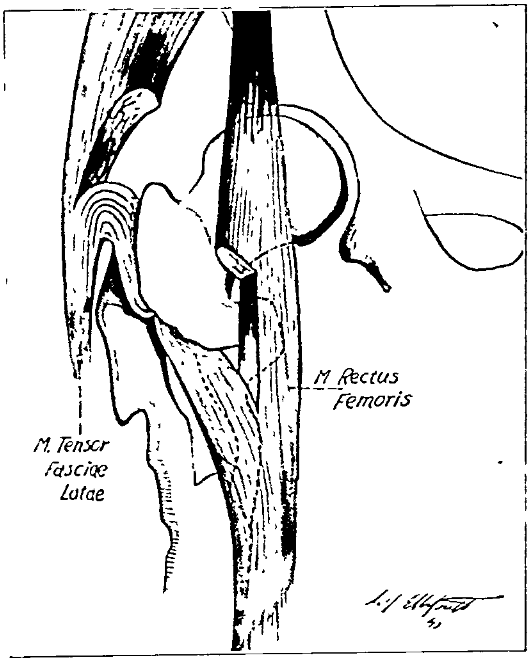


Fig. 2-B
Case A-23.

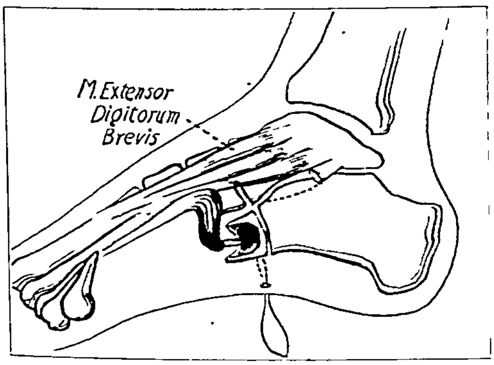


Fig. 2-C
Case A-44.

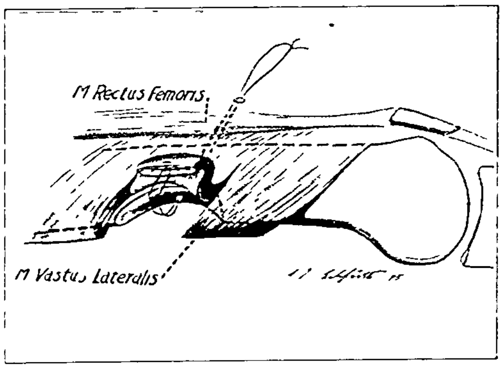


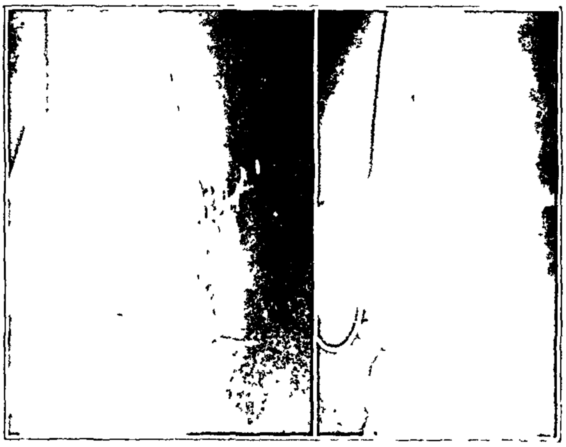
Fig. 2-D
Case A-32.

Examples of muscle pedicles used in filling bone defects.

peripheral-nerve lesions; the false motion and shortening of the extremity favor easy approximation of the nerve, without tension.

Closure of the skin and superficial fascia over the wound should be done, even if it is necessary for the operator to do a relaxing incision on one or both sides of the original wound, displacing the skin and subcutaneous tissue so that closure may be made without tension, and then covering the skin defect so formed by a split-thickness skin graft. In many instances, particularly in the lower extremities, later bone-grafting will be required to give the involved bone sufficient strength to fulfill its function of weight-bearing.

The routine procedure includes an evaluation of the patient's general condition and a study of the local pathological conditions. Wound cultures are done routinely, although the organisms found have in no instance caused a change of plan. The ordinary roentgenographic studies are made. Then, after lipiodol injection of the sinuses, stereoscopic



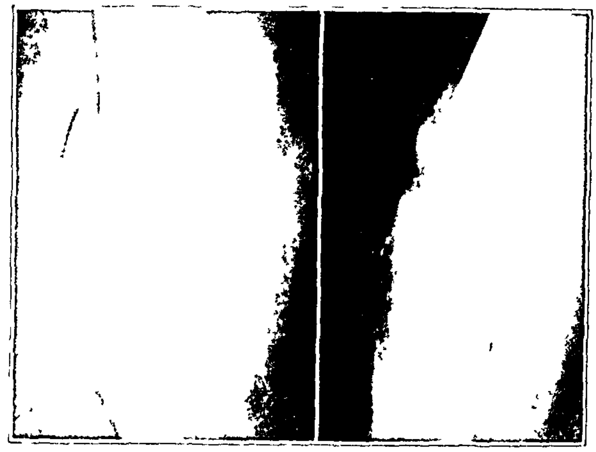


FIG. 3-A FIG. 3-B

Case *A*-34. Patient sustained a compound T fracture of the femoral condyles in a rock slide on February 26, 1945, with resultant chronic osteomyelitis of the medial condyle and a purulent arthritis of the knee joint. Excision of all devitalized and infected tissue and arthrodesis were performed on July 20. The surgical wound healed in fifteen days; this terminated a five-month period of persistent purulent drainage.

Fig. 3-A: Preoperative lipiodol study was made on May 31, 1945.

Fig. 3-B: Postoperative roentgenograms, taken on October 10, 1945. Clinically, the arthrodesis is secure.

FIG. 4-A FIG. 4-B

Case *A*-35. Patient sustained a perforating gunshot wound of the right knee on December 15, 1944, with loss of anterior soft tissues, and a compound fracture of the lower pole of the right patella, with resultant chronic osteomyelitis. Excision, patellectomy, and plastic closure of the wound were performed on January 16, 1945. The surgical wound healed in eighteen days; this terminated one month of mild purulent drainage. Eight months after operation there was 25 degrees of painless weight-bearing motion in the knee joint.

Fig. 4-A: Roentgenograms taken on January 15, 1945.

Fig. 4-B: Roentgenograms taken on September 13, 1945, eight months after operation.

views are taken to show the extent and ramification of such tracts. The patient is placed on a high-protein diet, supplemented by a high vitamin intake, with replacement of whole blood and plasma as necessary.

At the optimum time, as early as possible, the patient is operated upon. In so far as possible, a pressure-cuff tourniquet is employed. Methylene blue is injected into all sinus tracts under slight pressure; this aids *en bloc* excision by delineating the tortuous, and often multiple, sinus tracts. An appropriate surgical approach is made, which should always extend well into normal tissue, both proximal and distal to the diseased condition. This is essential, not only for complete visualization of the diseased tissue, but because peripheral nerves and important vessels must be isolated above and below the pathological process in order to preserve their integrity while the operator proceeds with the radical dissection. Also, such exposure is necessary for the proper selection of a portion of muscle to be sacrificed, if needed, by forming it into a pedicle. This is done in such a manner that the innervation and blood supply of the donor muscle and the blood supply of the pedicle will not

Case A-19 Patient sustained a perforating gunshot wound in the region of the left hip on August 8, 1944 This caused an incomplete femoral-nerve lesion and a compound fracture of the head of the left femur and adjacent acetabulum, with resultant chronic osteomyelitis and purulent arthritis of the hip joint Excision and arthrodesis were performed on November 24, 1944 The wound was partially closed, and had healed by second intention on the twentieth day after operation, terminating four months of constant purulent drainage Clinically, the hip fusion was solid in four months

Fig 5-A Preoperative anteroposterior roentgenogram of left hip, taken on October 7, 1944

Fig 5-B Lipiodol study, made on October 28, 1945

Fig 5-C Roentgenogram, taken on August 1, 1945, shows intra-articular bony fusion

Fig 5-D Photograph of the operative site in November 1945, one year after operation

Fig 5-A

Fig 5-B

Fig 5-C

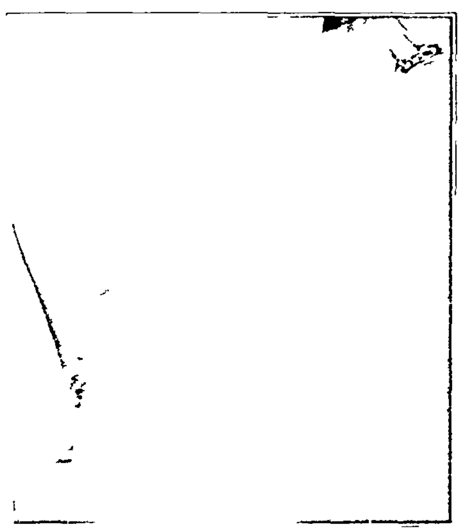


Fig 5-D

be jeopardized; the object is to ensure minimum interference with function of the part and a viable pedicle. All abnormal tissue—sinus tracts and infected granulation tissue, sequestra, eburnated and abnormal bone—and foreign bodies, if involved, are removed radically so that all remaining tissue appears normal and has good vascularity. The tourniquet is then released and hemostasis is obtained. The bone defect, if shallow, will be obliterated by slight displacement of the surrounding muscles; if deep, a muscle pedicle is formed and sutured into the defect (Figs. 2-A to 2-D). Deep vertical mattress sutures of 0.009 stainless-steel wire are placed, and the wound edges are lightly approximated.

F G. 6-A

Case A-27. Patient sustained a compound, comminuted fracture of the left femoral shaft, with resultant chronic osteomyelitis, caused by a ricocheting bullet on July 5, 1944. Excision was performed on January 10, 1945. The wound healed completely after eight weeks of thin serous drainage from one sinus; this terminated six months of constant copious purulent discharge.

Fig. 6-A: *Lipiodol study on December 15, 1944*, showing the extent of the bone defect and the metallic foreign bodies.

Fig. 6-B: Anteroposterior and lateral roentgenograms taken on September 27, 1945. The union does not *appear to be solid, although the patient* had been ambulatory in an ischial weight-bearing brace for two months, without untoward symptoms.

Fig. 6-C: The appearance of the operative site in November 1945, showing the extent of the surgical approach made in order to obtain adequate exposure. At this time, ten months after operation, there is 95 degrees of painless, active motion of the knee joint from the extended position.

FIG. 6-B

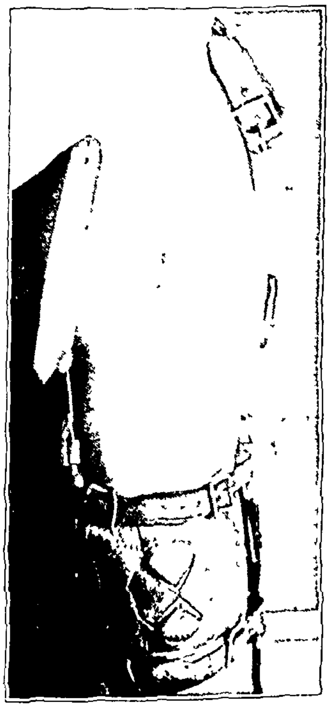


FIG. 6-C

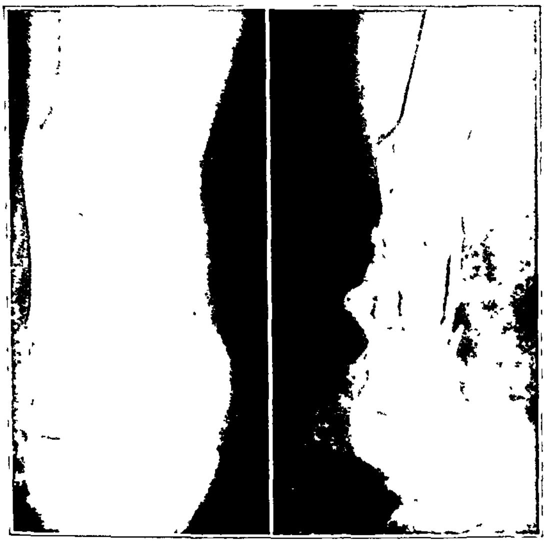


FIG. 7-A

FIG. 7-B

Case A-33. A shell fragment perforated the lower thigh on April 16, 1944, and the patient sustained a compound, severely comminuted fracture of the lower femur, with resultant chronic osteomyelitis. Alignment was maintained by skeletal traction, and partial bony union occurred. Surgical excision was performed on October 16, 1944, and the wound healed in four weeks; this terminated seven months of mild purulent discharge. In September 1945, eleven months after operation, there was shortening of one and one-quarter inches and 105 degrees of painless knee motion from the extended position.

Fig. 7-A: Lipiodol study made on October 7, 1944.

Fig. 7-B: Roentgenograms taken on August 20, 1945.

A direct or an eccentrically placed drain is removed in forty-eight hours. A few wounds have been closed by secondary suture five to seven days after excision of infected tissue. Appropriate plaster-cast immobilization is applied, as indicated. All patients received penicillin intramuscularly for three weeks, and no sulfonamides were used. The initial dose of 25,000 units of penicillin is administered at the time of operation and repeated every three hours for two weeks. During the third week the dosage is gradually decreased and

FIG. 8-A

FIG. 8-B

Case A-23. Patient sustained a gunshot wound of the right hip on April 12, 1945, causing a complete lesion of the sciatic nerve and a compound, comminuted fracture of the right trochanter, with resultant chronic osteomyelitis. Excision and muscle-pedicle transplant (Fig. 2-B) were performed September 5, 1945. The wound healed *per primam* on the twelfth day after operation, after five months of moderate purulent drainage.

Fig. 8-A: Preoperative lipiodol study made on August 23, 1945.

Fig. 8-B: Postoperative roentgenograms taken on October 5, 1945.

the time interval is increased, until the patient receives 10,000 units every six hours on the twentieth and twenty-first days.

Forty-four foci of infection in forty-two patients have been treated by this method. Good results were considered to have been obtained in forty-three; there was only one failure in which drainage persisted, and this was healed by a second excision. The average period of drainage prior to operation was twenty weeks; after operation it was three and one-half weeks. Twenty-one wounds were healed completely at the time of first inspection,—usually ten to fifteen days after operation. Of the remaining twenty-three patients, in all but three the wounds had healed completely within five weeks; these three showed a decreasing amount of serous exudate for eight weeks, with no recurrence after five or six months of activity.

The one failure (Case *A*-25) was due to incomplete removal of eburnated bone. At the time of the first excision there was some question as to the advisability of removing a small projection of the proximal femoral fragment, which was somewhat eburnated. At the time of the second excision it was found that this area had subsequently become sequestrated and was the cause of the continued drainage. Such a finding emphasizes the necessity for radical excision.

In four instances there was involvement of a major joint, with suppurative arthritis. One of these patients (Case *A*-34) had chronic osteomyelitis of the entire medial condyle of the femur, with suppurative arthritis of the knee joint, secondary to a compound T fracture of the femoral condyles, which had been sustained in a rock slide. Adequate exposure was obtained through the medial peripatellar

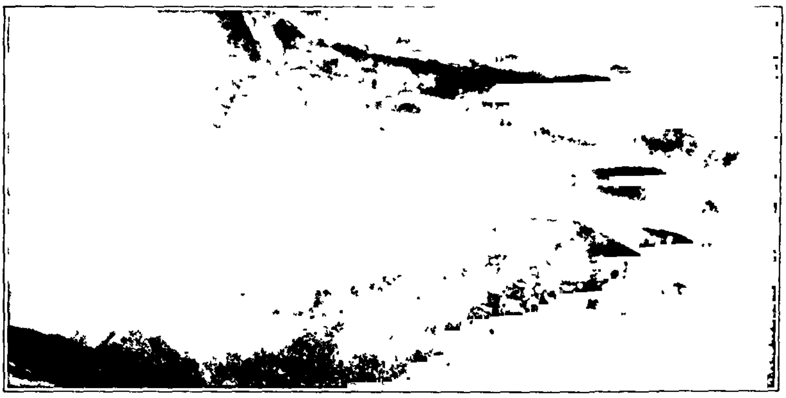


Fig. 9-A

Fig. 9-B

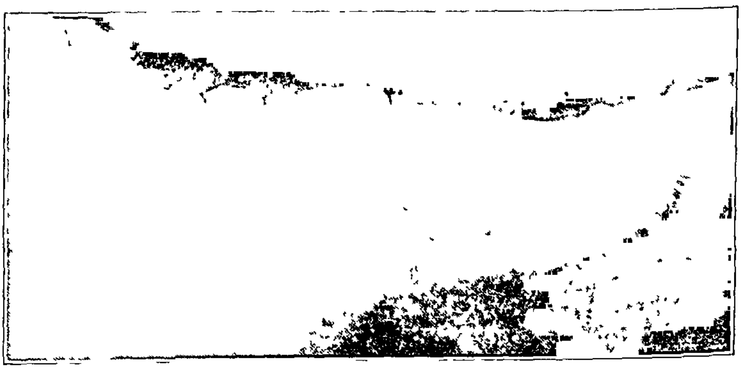


Fig. 9-C

Case *A*-44. Patient sustained a gunshot wound of the left foot on October 6, 1944, causing a compound, comminuted fracture of the cuboid tarsal and the third, fourth, and fifth metatarsals; there was loss of substance, with resultant chronic osteomyelitis. Excision and muscle-pedicle transplant (Fig. 2-C) were performed on February 16, 1945. The wound healed in fourteen days; this terminated a continuous mild purulent exudate of four months' duration. In September 1945, seven months after operation, the walking gait was normal, but running disclosed a limp.

Fig. 9-A: Preoperative roentgenogram taken on December 4, 1944, through a plaster cast, showing diffuse osteomyelitis of the cuboid tarsal.

Figs. 9-B and 9-C: Postoperative roentgenograms taken on July 17, 1945, five months after operation.

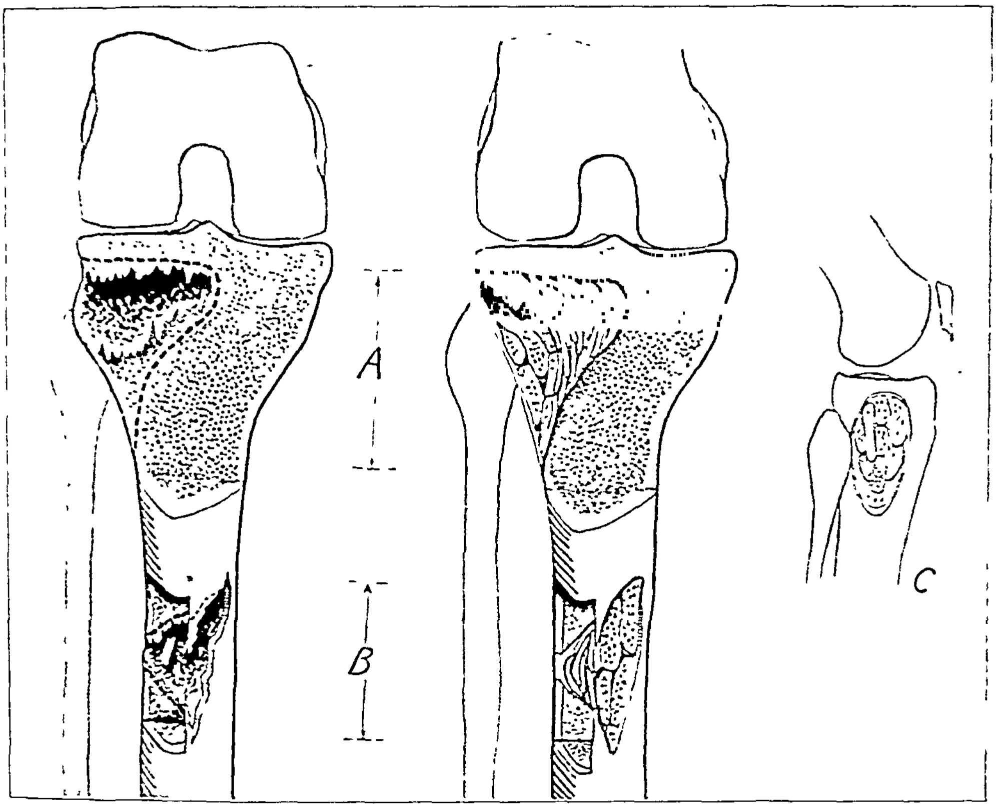


Fig. 10

Shows two typical defects, before and after excision and iliac-bone graft.
A: *Coronal section of a large defect and detail of "bricking-in" the iliac chips.*
B: Shows partial coronal section.
C: Sketch of lateral view, showing the surface of the grafted area.

approach. Excision was carried out as outlined, with removal of all necrotic tissue, including most of the medial condyle. (The cruciate ligaments and menisci could be identified by anatomical location only.) The joint was leveled by ostectomy of the lateral femoral condyle. All the remaining articular cartilage was excised, and the part was immobilized in a spica cast. The wound had completely healed in two weeks, at the time of the first dressing, and has so remained (Figs. 3-A and 3-B).

The second patient (Case *A*-35, Figs. 4-A and 4-B) had chronic osteomyelitis of the right patella; the lower pole of the patella, the origin of the patellar ligament, and the anterior soft tissues had been shot away five weeks before. Upon removal of the granulation tissue, the articular cartilage of the femoral condyles presented itself; and, after patellectomy, inspissated pus was observed in the folds of the suprapatellar pouch. Smear and culture showed *Escherichia coli*. The joint was thoroughly irrigated with two liters of normal saline; and fifty cubic centimeters of penicillin solution (500 units per cubic centimeter) was instilled. Plastic closure of the skin and superficial fascia was accomplished. Healing was complete within three weeks. Six months after operation there was 25 degrees of painless motion, active and passive, from the extended position.

The third patient (Case *A*-19) had chronic osteomyelitis of the head of the left femur and the adjacent acetabulum, with suppurative arthritis of the hip joint, secondary to a perforating bullet wound (Figs. 5-A to 5-D). Exposure was made through the lateral approach. The roof of the acetabulum and about two thirds of the superior portion of the femoral head were excised. As much of the remaining articular cartilage as could be reached without dislocating the hip was removed, and the dead space was partially oblit-

Fig. 11-A

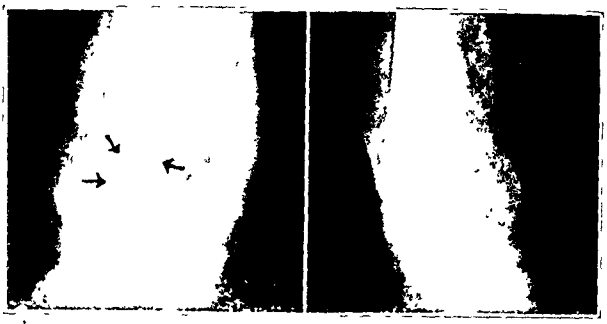


Fig. 11-B

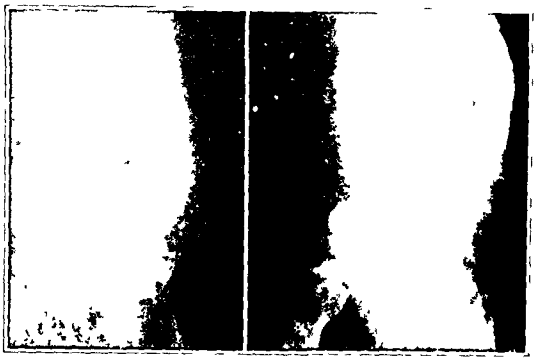


Fig. 11-C

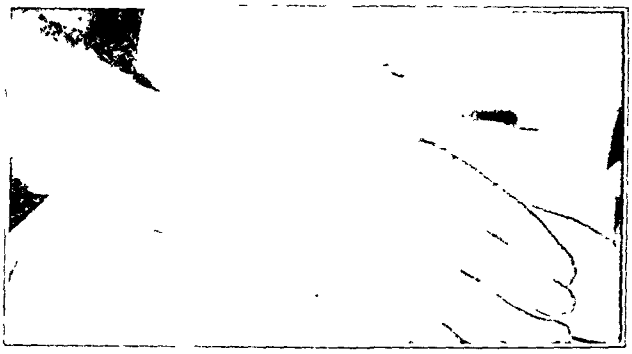


Fig. 11-D

Case *B*-1. A shell fragment penetrated the dorsum of the right wrist on January 20, 1945, with loss of soft tissue, including the extensor tendons to the fingers, and a compound, comminuted fracture of the right lower radius and ulna, with resultant chronic osteomyelitis of the radius. The infected bone was excised, a penicillin pack was inserted into the defect, and an abdominal-skin pedicle was prepared on April 27, 1945. Iliac-chip grafts were introduced into the defect on May 11, 1945. The abdominal pedicle was swung, after the scar over the dorsum of the wrist had been completely excised, on June 12, 1945. The last stage of the abdominal pedicle was completed on July 3, 1945, and the wound had healed completely in ten days, terminating three months of mild purulent drainage.

Fig. 11-A: Preoperative lipiodol studies in the anteroposterior and oblique views, made in April 1945.

Fig. 11-B: Postoperative roentgenograms taken on May 30, 1945. The iliac grafts are delineated by arrows.

Fig. 11-C: Postoperative roentgenograms taken on August 15, 1945.

Fig. 11-D: Photograph of the donor and recipient sites in November 1945, prior to free tendon grafts to the extensor tendons of the fingers.

erated by upward displacement of the femoral head. The wound was partially closed, and had healed by second intention within three weeks. Two subsequent flare-ups (with pain and fever, but no discharge) during the third and fifth weeks after operation were controlled with penicillin, which was finally discontinued seven weeks after operation. The patient has been ambulatory in an ischial weight-bearing brace for the past seven months, and has had no pain or drainage.

The fourth patient (Case *A*-9) had chronic osteomyelitis of the lateral condyle of the humerus, involving the left elbow joint, secondary to a compound fracture of the humeral condyles, caused by a perforating shell fragment. Most of the joint had become walled off, and healing occurred within fifteen days after excision of the infected bone and soft tissue. Three months after operation, the patient had 40 degrees of painless active and passive motion from the right-angle position.

OBLITERATING THE DEFECT BY ILIAC GRAFT

In a large group of cases (31 per cent. in this series), the defect cannot be obliterated by a muscle transplant. The anterior surface of the tibia, the radial styloid, and the calcaneus are covered only by integument, fascia, and ligamentous and tendinous structures, and muscle tissue is not available for a transplant.

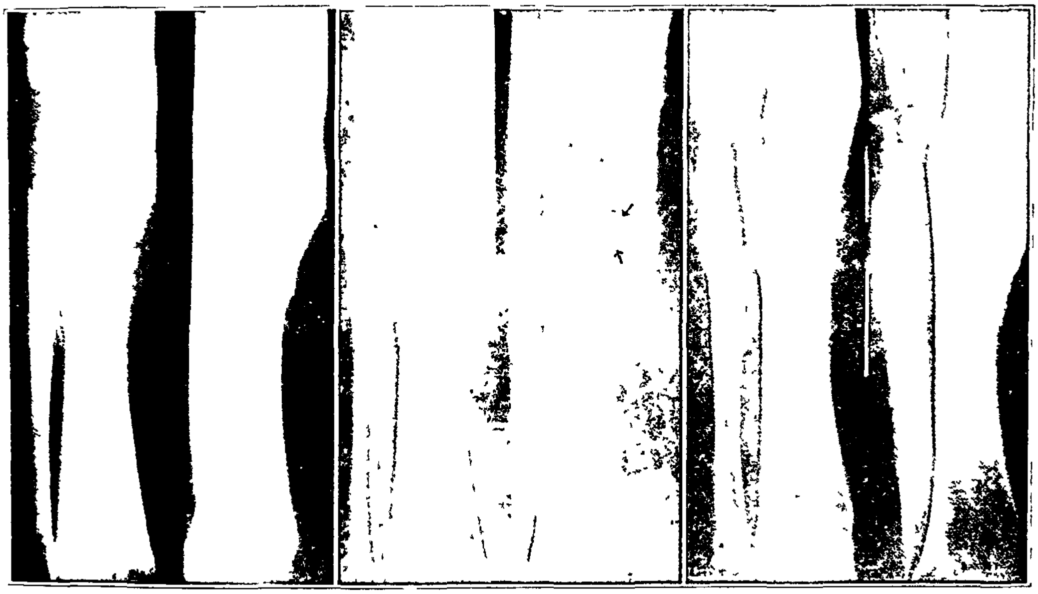


FIG. 12-A FIG 12-B FIG. 12-C

Case B-14. A shell fragment perforated the patient's right leg on October 11, 1944, causing a complete paralysis of the peroneal nerve and a compound, comminuted fracture of the tibial and fibular shafts, with resultant chronic osteomyelitis of the tibia and persistent purulent drainage Excision was performed on March 28, 1945, and a penicillin pack was inserted The defect was filled with iliac chips on April 18, 1945. Sequestrectomy (a fragment of tibial cortex, not iliac graft) was performed on August 15, 1945. The wound had healed by second intention by October 30, 1945

Fig. 12-A: Preoperative lipiodol study, made on March 8, 1944.

Fig. 12-B: Anteroposterior and lateral roentgenograms taken on May 10, 1945, three weeks after graft with iliac chips, show the sequestrum, delineated by arrows, and the appearance of the iliac bone filling the defect.

Fig 12-C: Postoperative roentgenograms taken on September 27, 1945, showing consolidation of iliac grafts.

The tibial defects are usually deep and, after excision, present a rigid-walled cavity, which, by the usual methods, will take months to be filled. The problem was to find some method of filling these deep defects which would allow prompt healing. In seven patients (Cases 36, 37, 38, 39, 40, 41, and 42 of Group *A*) the area of destruction in the tibia was mostly in cortical bone or along the lateral or posterior surface. After excision, the superficial defect was obliterated by closure of the skin and subcutaneous tissues or muscle, depending upon the location of the osteomyelitic focus. There was prompt healing in all.

In June 1944, a large purulent, chronic osteomyelitic focus in the upper tibial area was excised radically. The bone defect was filled loosely with gauze dressings, wrapped around a Dakin tube, through which penicillin solution could be instilled four times daily. On the eighth day the wound was inspected, and it appeared exceptionally clean; the entire bony defect was thinly covered with healthy "velvety-appearing" granulations. If viable (and therefore infection-resistant) tissue could be placed in this defect, it seemed that the prospect of healing would be excellent. The utilization of a pedicle of subcutaneous fat had already proved impractical. To use a pedicle formed from adjacent leg muscles was not feasible, as too often this would cause permanent disability from loss of the physiological function of the sacrificed muscle. Since Abbott showed that a graft of cancellous iliac bone is rapidly revascularized and becomes part of the surrounding bone in a comparatively short interval, it was decided to try this type of graft in filling such defects; meanwhile, systemic penicillin was used to ensure that infection would cause minimum interference with healing. If this procedure proved successful, considerable time would be saved, since further bone-graft operations would be unnecessary. At first, large pieces of ilium, including the iliac cortex, were used, but with indifferent success. In fact, in two of

the first three cases in which this was attempted, suppuration continued. Upon analysis of these two failures, it was noted that, when the grafts were disturbed, the cancellous portion would bleed (showing early revascularization), while the cortical portion of the graft showed definite suppuration. It was then decided to use only small cancellous iliac chips (approximately four centimeters long, one centimeter wide, and three millimeters thick), from which all cortical bone had been removed. Since this type of graft has been used, there has been no deep sequestration or formation of chronic sinus tracts.

The procedure in this second group (Group *B*) is complete excision of all infected and avascular tissue, as in Group *A*. The bone defect is lightly filled with gauze dressings, wrapped around either a Dakin tube or male catheter, which extends through the gauze dressing and cast. Through this, from two to four cubic centimeters of penicillin solution, containing 250 units per cubic centimeter, are instilled four times during the twenty-four hours; and 25,000 units are administered intramuscularly every three hours. After from seven to ten days, depending upon the size of the defect, the wound is inspected; the defect has always been found to be covered with a thin layer of healthy granulations.

The patient is operated upon the next day. The appropriate iliac crest is prepared in the usual manner. Sufficient bone is removed in thin strips, and the cortex is discarded. The iliac wound is closed before the recipient site is exposed, in order to prevent any cross contamination. The granulating defect is thoroughly and gently irrigated with from one to two liters of normal saline; and the surrounding skin is prepared with ether, alcohol, and merthiolate, care being taken to get none in the recipient site. The grafts are then "shingled" or "bricked" into place so as to fill the defect (Fig. 10). The wound is closed, except for a small opening or vent directly over the grafts, which is maintained by a vaseline-gauze wick; and the part is immobilized in plaster. In this way the entire extremity is placed at rest, the iliac grafts are immobilized, and provision is made for drain-

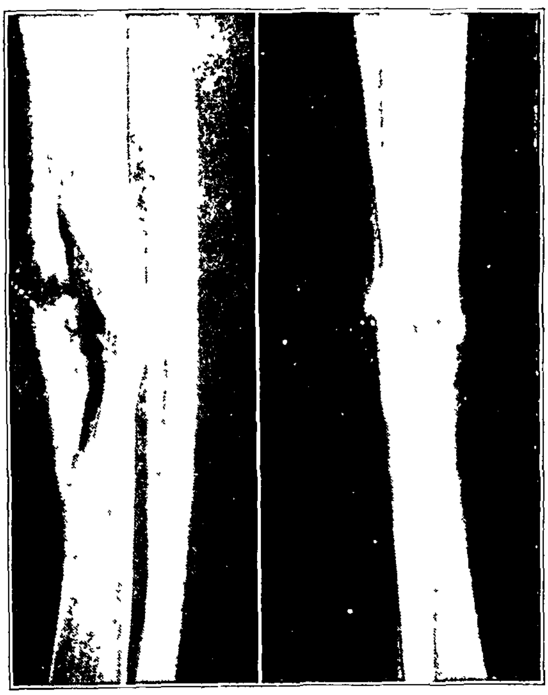


Fig. 13-A

Fig. 13-B

Case *B*-13. Patient sustained a perforating gunshot wound of the left leg on September 22, 1944, causing a compound, comminuted fracture of the mid-tibial shaft, with resultant chronic osteomyelitis. Excision was performed and a penicillin pack was inserted on May 4, 1945. Iliac chips were placed in the bone defect on May 25, 1945. The surgical wound healed on June 14, 1945, and remained healed, except for serous drainage from a "skinned" area for one week in July 1945.

Fig. 13-A: Preoperative roentgenograms taken on January 13, 1945.

Fig. 13-B: Postoperative roentgenograms taken on September 26, 1945.

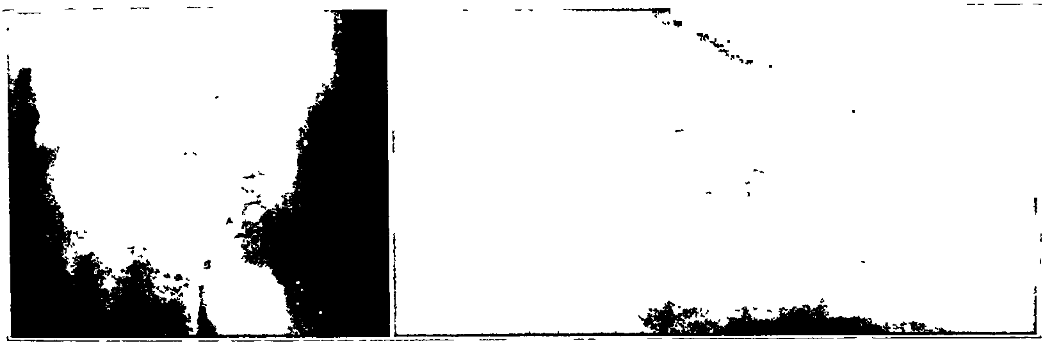


FIG. 14-A

FIG. 14-B

Case *B*-19. Patient sustained a perforating shotgun wound at close range on December 25, 1944, with loss of the neck of the talus and the scaphoid tarsal, and considerable soft-tissue injury. Débridement, with vaseline gauze in wounds and plaster-cast immobilization, was performed the day of injury. Secondary closure was performed on the dorsal wound on February 2, 1945. Iliac chips were placed in the bone defect on February 27. A thin split-thickness skin graft was applied on April 9; it healed in three weeks. The patient has been ambulatory for seven months, with a barely perceptible limp, but with occasional slight, recurrent serous drainage. The sinus was explored and found to be subcutaneous only (not entering the bone-graft area). There has been no drainage since.

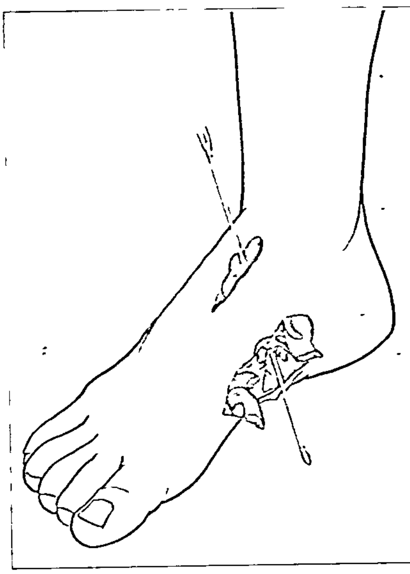


FIG. 14-C

FIG. 14-D

Fig. 14-A: Roentgenograms taken on December 25, 1944, the day of injury.

Fig. 14-B: Roentgenograms of August 8, 1945; the iliac grafts, outlined with arrows, have taken on the appearance of a tarsal bone

Fig. 14-C: Sketch of the injury.

Fig. 14-D: Photograph of the foot in November 1945.

age of exudate into the cast. Twenty-five thousand units of penicillin every three hours is continued intramuscularly for one or two weeks, depending upon the clinical course of the patient.

Several methods of local postoperative care have been tried, but with the one men-

FIG. 15-A

FIG. 15-B

FIG. 15-C

Case *B*-20. Patient sustained a perforating gunshot wound of the right heel on August 28, 1944, causing a compound, comminuted fracture of the right calcaneus, with resultant chronic osteomyelitis. Excision and closure were performed on January 30, 1945, but drainage persisted. Excision was performed and penicillin pack placed in the defect on March 9, 1945. Iliac chips were placed in the defect on March 23, 1945. The wound had healed on April 23, 1945, and the patient has been doing light duty for four months (concluded in October 1945) without complaint. Walking gait shows no limp, but a perceptible limp is present when running.

Fig. 15-A: Preoperative lipiodol study made on December 15, 1944.

Fig. 15-B: Postoperative roentgenograms taken on May 14, 1945.

Fig. 15-C: Photograph of the foot in November 1945.

tioned the wounds have uniformly appeared better. In two early cases, treated without plaster, it was felt that at least a part of the failure was due to pocketing of the exudate, which prevented the granulations from growing up, engulfing the grafts, and incorporating them solidly into the recipient site by organization.

The first cast is changed in three weeks and the wound is inspected. In small defects (two centimeters in diameter) the area will be found to be ready for secondary closure. In one case (Figs. 11-A to 11-D) an abdominal pedicle, previously prepared, was swung into position at this time, with complete and prompt healing. In larger defects the vaseline wick is reinserted and the part is placed in a cast for an additional three weeks, during which time the patient may be up in a wheel chair only. In most instances the wound has healed, at least sufficiently so that closure by simple plastic procedures may be accomplished. Such procedures have included simple wound revision and secondary closure, with

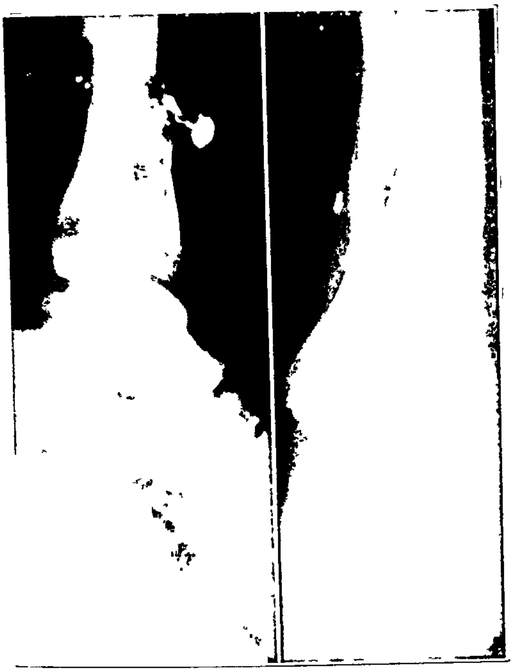


FIG. 16-A

FIG. 16-B

Case B-16. A shell fragment penetrated the patient's left leg on February 15, 1945, causing a compound, comminuted fracture of the left lower tibial shaft, with resultant chronic osteomyelitis. Excision was performed and a graft of iliac chips was applied to the defect on August 7, 1945 The wound had healed by second intention on September 15, 1945

Fig. 16-A: Preoperative lipiodol study made on July 11, 1945.

Fig. 16-B: Postoperative roentgenograms taken on October 10, 1945.

Fig. 16-C: Photograph of the operative site in November 1945. (The patient is in a wheel chair because of a fracture of the right femur and palsy of the peroneal nerve on the right side, sustained in the original injury.)

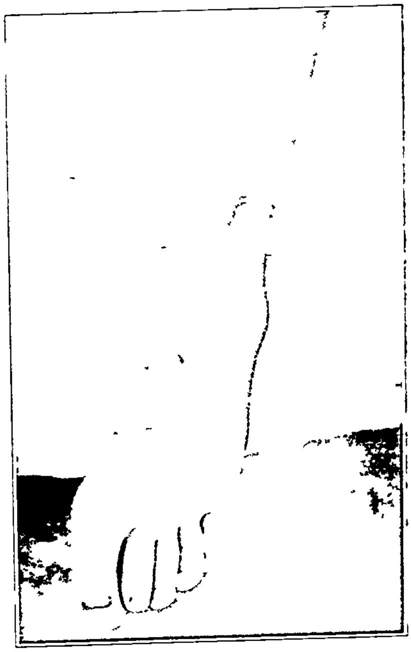


FIG 16-C

relaxing incision when necessary, pinch grafts, or a pedicle graft. There are three criteria for timing secondary or plastic closure: first, that no sinus tracts are present; second, that healthy granulations have covered all the graft and the recipient bone; and third, that the surrounding soft tissues are not oedematous or inflamed. If these criteria do not obtain, moist dressings of normal saline are applied every four hours for from two to four days, through a window in the cast. This usually suffices to prepare the area for the procedures mentioned.

In three instances, complete closure over the grafts was done primarily, with an eccentrically placed needle for introduction of the penicillin solution. Results in these cases were good, but it was believed that the benefit was derived from the needle as a drain to relieve the wound of exudate, rather than from any beneficial results from local penicillin. In two cases (B-16 and B-17)—both defects of the tibial shaft—the excision and graft were accomplished at one operation. Healing occurred in both, although it was delayed by an estimated two to three weeks in each instance.

Twenty cases * of chronic osteomyelitis have been treated by radical excision and a graft of iliac bone. Results were considered good when the wound healed within nine or ten weeks,—usually by second intention or with the aid of skin grafts or plastic revision; and fair when complete healing occurred, which, however, took longer than ten weeks. Failure was classified as persistence of drainage after four months. The results were good in eight cases and fair in eight cases; failure occurred in four cases. Four of the patients rated as having fair results required a single curettage of a persistent sinus, with serous drainage. These patients have been observed for an average of nearly five months since curettage, and no subsequent drainage or inflammation has occurred. One other case rated as a fair result required a sequestrectomy after the iliac-bone graft; healing was then prompt. The sequestrum had inadvertently been overlooked at the time of the first operation, and was apparent in the roentgenograms taken after the iliac graft (Fig. 12-B). This is a reminder that the entire area should be explored thoroughly at the primary operation, and that no overhanging ledges should be left. "Cup-like", rather than "saucer-like", defects have been the aim in excising the deep osteomyelitic foci. If a sinus persists for as long as two weeks after removal of the cast, surgical exploration is indicated. Of the five cases mentioned, prompt healing followed such treatment in all, and the results might have been classed as good if exploration had been done early.

Evaluation of the results shows that the failures were either in cases which had large bone defects (approximately 4 to 4.5 centimeters in diameter) in the upper tibia, or in those in which a large defect in the skin and subcutaneous tissue near the ankle was present. Observation of the cases with bone defects in the tibia indicates that the revascularization of the grafts is fast enough to overcome necrosis only if the diameter of the graft bed is not greater than 2.5 to 3.0 centimeters. In the future, if the diameter is greater than 3.0 centimeters (the length being of little concern), the surface of the bone will be skived down so that the defect does not form such a deep well (Fig. 10, *A*). The two instances rated as failures, in cases with large skin defects and subcutaneous defects in the lower tibia, show good results by roentgenogram, as far as the iliac-bone graft is concerned. Clinically, the wound remains as a shallow granulating area with a mild serous exudate, and no sinuses are present. All that is needed for complete healing is a pedicle graft from the opposite calf, which is now in the process of being prepared. In the future, in this type of case a pedicle graft will be made ready to swing at the end of from three to six weeks after the iliac graft has been accomplished, depending upon the appearance of the wound. This was done in one instance (Case *B*-1). Whatever plastic repair of the skin is necessary should be completed within from six to seven weeks after the iliac graft. All of the grafts, and therefore the bone defect, will be fully organized at that time.

Recently, in two cases of chronic osteomyelitis of the femoral shaft, the deep defects were filled with iliac-bone chips, in order to establish the relative merits of the two methods of obliterating "dead" space in this area. If successful, subsequent bone-grafting would be unnecessary and much time would be saved. In both instances, however, purulent drainage continued and many of the grafts sequestrated, necessitating reoperation for muscle transplant after removal of all grafts. The cause of these two failures is obscure, since the same method has been successful in the tibial shaft; but, as a consequence, the use of iliac-bone chips in any defect that can otherwise be obliterated by muscle tissue is not advocated. These two cases are not included in the statistical analysis, since both were for trial only in an area where muscle transplants had already proved successful.

A method which yields only 40 per cent. of good results is subject to just criticism. It is now clear, however, that, of the four poor results, all were foredoomed to failure, and also that many of the cases in which the results were rated as fair could have been healed

* The twenty-first case so treated (a defect of the tibial shaft) shows a slight serous drainage at the end of the sixth week after operation, and complete healing within the ensuing two weeks is anticipated. However, this case is not included in the statistical analysis.

in a shorter period of time. With the benefit of experience and improvement in technique, the percentage of good results should improve. Certainly with the present bacteriostatic drugs and the prospect of still more effective bacteriostatic, and possibly bactericidal, agents in the near future, the incidence of hematogenous osteomyelitis will be exceedingly small. With good surgical technique and such drugs, bone infection following elective surgery and compound fractures should be negligible. However, in the few instances which will occur, radical surgical excision of all devitalized tissue and immediate grafts of cancellous iliac bone should be effective in a high percentage of cases.

SUMMARY

1. The prompt and permanent healing of chronic pyogenic osteomyelitis is imperative, in order to prevent the many serious complications and sequelae and to permit early reconstructive surgery, when necessary.

2. With the present-day bacteriostatic drugs, more radical surgery can be accomplished without danger to life or limb.

3. Sixty-four separate foci of chronic osteomyelitis in sixty-one male patients, between eighteen and thirty-seven years of age, have been treated during the past sixteen months.

4. Early healing (within ten weeks) occurred in 78.1 per cent. Including the eight cases in the iliac-graft series, in which healing was delayed over the ten-week period, and the one case in which re-excision was necessitated by a secondary sequestration, complete healing occurred in 93.7 per cent.

5. The method used and advocated is founded upon the principle of complete excision of an infected and avascular tissue, obliteration of the "dead" space, and wound closure. Wherever possible, obliterating the dead space with viable muscle has been the method of choice, since 97.7 per cent. of the wounds in this group healed promptly. Bone-grafting should be done later, if necessary, to reinforce any bone weakness. In the calcaneus, the anterior surface of the tibia, and the radial styloid, obliterating the dead space with grafts of cancellous iliac bone has shown definite merit and has been time saving.

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METATARSAL FRACTURES

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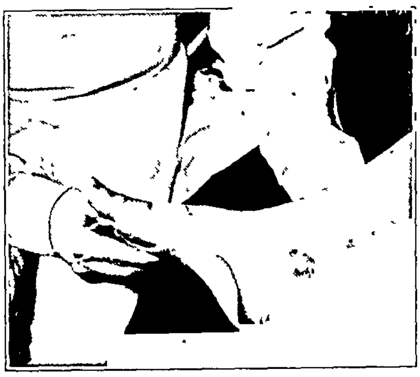
Foot trauma, both in industry and in the Armed Forces, is probably one of the most frequent contributors to the loss of vitally needed man-hours. To rehabilitate the injured man as rapidly as possible, without in any way jeopardizing his physical well-being, presents a major problem, the answer to which would seem to lie in a method of treatment which would minimize the period of disability and discomfort, yet produce the desired end result. Experience with the treatment of fractured metatarsals over a three-year period leads the author to believe that the type of treatment described herein has proved its value and efficacy in terms of the short period of disablement experienced and the excellent end results obtained.

REVIEW OF CURRENT METHODS OF TREATMENT

Up to the present time, the accepted treatment for fractured metatarsals has been rigid immobilization by means of a plaster cast, extending from the toes to the tibial tubercle, care being taken to mold the longitudinal and transverse arches of the foot. In only a few instances has any other form of treatment been advocated. For example, Christopher recommends the Davis splint, which consists of a flexed wooden splint applied to the sole of the foot in an attempt to maintain the longitudinal and transverse arches. However, in the use of this splint, weight-bearing is not allowed for from four to six weeks. Gebhard suggests a Jones bar under the shoe, with weight-bearing in one week; and Berkman uses the regulation army shoe as a splint, without orthopaedic modification. In the last two instances, however, the patient receives support only while actually wearing the shoe, and he is limited to the use of one particular shoe until the fracture has healed. Sirbu and Palmer, in their treatment of march fracture, use the metatarsal pad and strapping, plus a metatarsal bar; the period of non-weight-bearing is twenty-one days, during which time no work is performed.

TREATMENT USED IN CASES STUDIED

The treatment used in this study was the application to the foot of a simple molded leather arch, with or without a metatarsal pad of sponge rubber. The leather arches were of a stock variety, and were applied to the foot by means of adhesive strapping. In the first half of the study a long anterior stirrup of adhesive strapping was used to immobilize the foot and ankle, and to hold the leather arch firmly to the foot. This strapping extended to the tibial tubercle, holding the foot in neutral position as regards eversion and inversion,



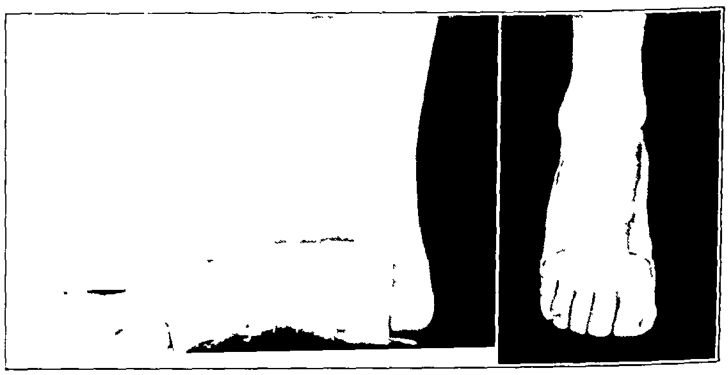


FIG. 1-A FIG. 1-B FIG. 1-C

Show leather arch applied to foot and held in position by adhesive strapping.

TABLE I

FRACTURES OF METATARSALS IN SIXTY-ONE CASES

Number of Metatarsals Fractured	Bones Involved	Number of Cases	Total
1	First metatarsal	16	
1	Second metatarsal	9	
1	Third metatarsal	7	
1	Fourth metatarsal	2	
1	Fifth metatarsal	8	42
2	First and second metatarsals	2	
2	First and third metatarsals	1	
2	Second and third metatarsals	3	
2	Third and fourth metatarsals	3	
2	Third and fifth metatarsals	1	
2	Fourth and fifth metatarsals	1	11
3	First, second, and third metatarsals	5	
4	First, second, third, and fourth metatarsals	1	
4	Second, third, fourth, and fifth metatarsals	1	
3	Third, fourth, and fifth metatarsals	1	8
Total			61

and in 90 degrees of dorsiflexion. The arch support was held firmly to the fore part of the foot by means of a strapping, similar to that used for an anterior metatarsal arch

As the study progressed, it was found that the long stirrup was not necessary, and short strips of adhesive tape were used to approximate the leather arch to the foot These strips did not extend above the malleoli, and thus allowed complete range of motion of the ankle joint (Figs. 1-A, 1-B, and 1-C).

Before the adhesive strapping was applied, the leg and foot were carefully cleansed and shaved, and three coats of tincture of benzoin were applied It was found necessary to change the strapping about once a week for an average period of four weeks Under this procedure the skin withstood the strapping with very little difficulty, and in only one case was any serious skin infection encountered At the end of about four weeks the strapping was removed, and the adhesive tape was trimmed away from the leather arch support The same arch support was then used in the patient's shoe for an additional period of one month. No massage, baking, or physiotherapy was used after the removal of the strapping

In the cases in which there was marked swelling, with or without abrasions and lacerations of the skin, the leather arch was held in place by means of an elastic bandage; and physiotherapy in the form of whirlpool treatment was used until the swelling had subsided and the skin had resumed the texture which would permit adhesive strapping to be applied over tincture of benzoin Approximately 25 per cent of the cases were treated in this manner.

TABLE II

RESUMPTION OF WEIGHT-BEARING AFTER INJURY

Weight-Bearing Begun	Number of Cases	Per Cent
Immediately	35	57 4
One to five days after injury	7	11 5
Six to ten days after injury	6	9.8
Over eleven days after injury *	13	21.3
Totals	61	100 0

* This group includes cases of severe contusion of the skin, flare-up of athlete's foot with cellulitis, and fractures with marked displacement An average of fourteen days were required before active unaided weight-bearing could be resumed.

TABLE III

INTERVAL BETWEEN INJURY AND RETURN TO REGULAR EMPLOYMENT

Time After Injury (*Days*)	Number of Cases
0	7
1 to 10	6
11 to 20	6
21 to 30	17
31 to 40	14
41 to 50	8
51 to 60	3
Total	61

SELECTION OF CASES

During the period from April 1941 to March 1944, ninety-eight cases of metatarsal fracture were seen. Ninety of these cases were treated in the manner described. Of the ninety-eight cases, thirty-seven were not included in this study for the following reasons:

1. Severity of the injury necessitated hospitalization in eleven cases. These included compound fractures and crushing injuries, which produced deep lacerations, with grossly contaminated wounds.

2. Additional fractures of the tarsal bones, tibiae, and fibulae were present in three cases.

3. The check at the end of six months revealed that twenty-three of these men were serving in the Armed Forces. This fact presupposes that they had satisfactory end results. Their absence from our physical and roentgenographic check-ups made it necessary to exclude this group.

The remaining sixty-one cases were used in this study, and included all types of fracture,—from simple fractures without displacement to displaced fractures with only 50 per cent. apposition; many comminuted fractures were present.

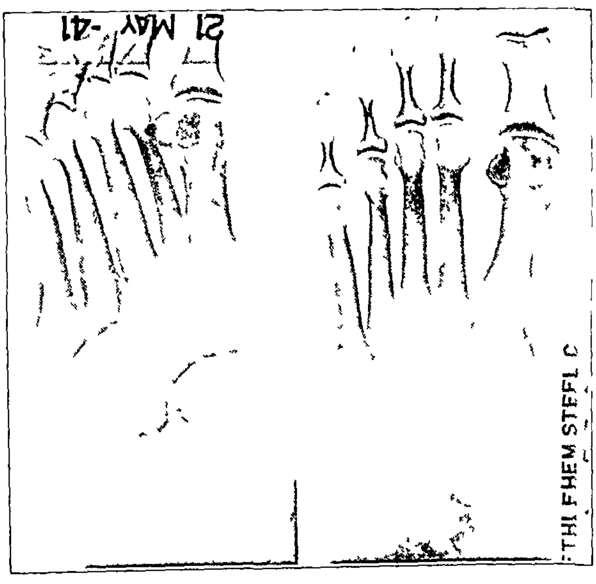


FIG. 2-A

FIG 2-B

J. K., aged forty-eight, received a comminuted fracture of the shaft of the first metatarsal of the left foot on May 21, 1941. He was released for special work the day of the injury; on June 20 he returned to his regular work. The end results were $A_4E_4F_4$; there were no complications.

Fig. 2-A: Roentgenograms taken on the day of injury.

Fig. 2-B: Views of the foot taken on January 5, 1943.

Fig. 3-A

Fig. 3-B

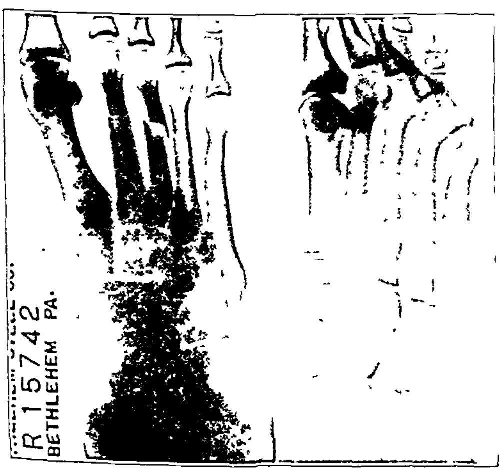
On February 26, 1942, B. B., aged forty-nine, fractured the distal third of the third, fourth, and fifth metatarsals of his right foot, with marked hematoma. He was released for special work the same day, and returned to his regular work on April 14. The end results were $A_4E_4F_4$; there were no complications.

Fig. 3-A: Shows the appearance of the foot on February 26, 1942.

Fig. 3-B: Roentgenograms taken on January 12, 1943.

ETIOLOGY

All of these fractures occurred as the result of direct trauma, such as a heavy object falling on the foot, or the foot being wedged in a moving machine. All the patients were men, from twenty to sixty-one years of age; and they were employed in varying types of jobs, including unskilled laborers, skilled mechanics, riggers, railroad brakemen, and office workers.



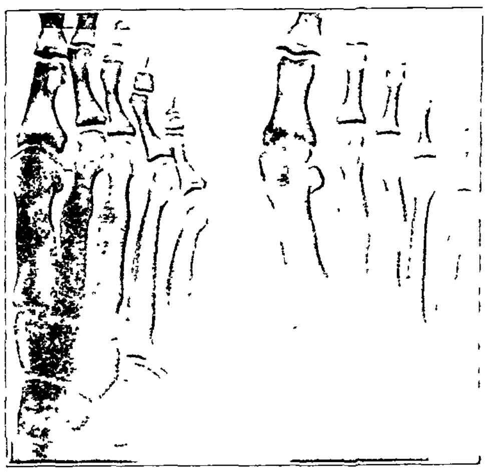


Fig. 4-A

Fig. 4-B

F. T., aged twenty-four, received a transverse fracture of the distal third of the first, second, and third metatarsals of his right foot on September 13, 1942. Three days later the patient was released for special work; he returned to his regular work on October 16. The end results were $A_1E_1F_1$; there were no complications.

Fig. 4-A: Roentgenograms taken on September 16, 1942.

Fig. 4-B: Showing end results.

FRACTURE SITE

In the study of sixty-one cases, forty-two cases involved the fracture of only one metatarsal, eleven involved two metatarsals, and eight involved three or more metatarsals. Table I illustrates the metatarsals involved.

WEIGHT-BEARING

Active weight-bearing was started immediately in more than one-half of the cases; in the remaining cases it was started within a comparatively short time after injury (Table II).

RETURN TO WORK

All men were kept on the job, doing either their regular work or selected work. Of the sixty-one patients, none remained away from some type of work for more than four days after injury. Table III shows the interim between the time of injury and the return to *regular* work. In this interim period, however, the men were not idle, but were employed at a selected type of work which, in the author's opinion, hastened their rehabilitation. The majority of men returned to regular work in less than forty days, and by the end of sixty days all had resumed their regular jobs.

In an effort to determine what conditions were conducive to an early return to work, the following factors were reviewed in these cases:

1. Type of injury to soft tissue (contusion, laceration, or maceration).
2. Type of fracture (from simple transverse fracture of one metatarsal, with no displacement, to complicated comminuted fractures of many metatarsals; there were also two compound fractures).
3. Age of the individual in respect to the reparative healing power of the bone.
4. Type of work performed (office work; skilled light work, as by an operator of a machine or lathe, or a craneman; arduous skilled work, such as by a repairman or rigger; and heavy labor, such as that performed with a pick and shovel).

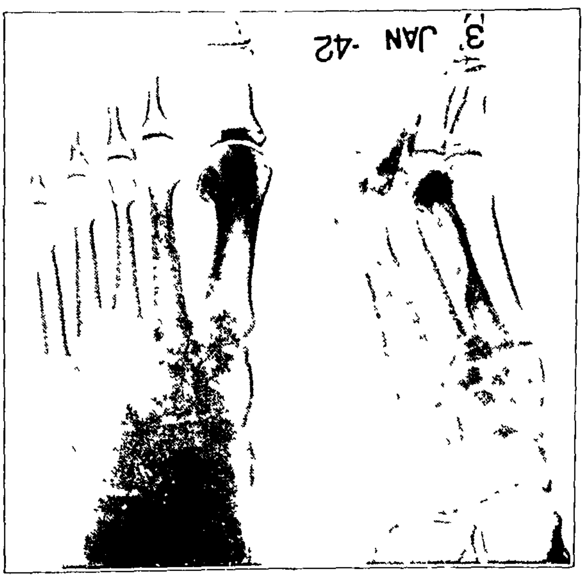


Fig. 5-A

Fig. 5-B

E. E., aged twenty-six, fractured the base of the third and fourth metatarsals of his left foot on January 3, 1942 (Fig. 5-A). He was released for special work the same day, and returned to his regular employment on March 19. The final rating was $A_1E_1F_1$. This man returned to his regular job with no loss of earnings and no symptoms. He was given a rating of A_1 because of widening at the base of the third metatarsal, as shown by roentgenogram on January 12, 1943 (Fig. 5-B).

FIG. 6-A

FIG 6-B

FIG 6-C

On September 29, 1942, H. L., aged forty-six, sustained a comminuted fracture of the distal third of the first metatarsal of the right foot. He was released for special work on the day of injury, and returned to his regular work on December 9, 1942, with no symptoms The end results were $A_3E_4F_4$. The A_3 rating was given because of thickening and shortening of the shaft of the first metatarsal, and distortion of the metatarsophalangeal joint.

FIG 6-A Roentgenograms taken September 29, 1942

FIGS 6-B and 6-C Follow-up roentgenograms taken on January 11, 1943 (FIG 6-B) and May 11, 1944 (FIG 6-C)

Immediate Return to Regular Work

The seven patients who returned to work immediately had only contusions of the soft tissues of the feet. Their fractures were simple, with very little displacement, and in each case only one metatarsal was fractured. Their ages ranged from twenty-seven to fifty-two years. Two were office workers, two were engaged in light labor, and three in skilled labor.

Ten Days or Less

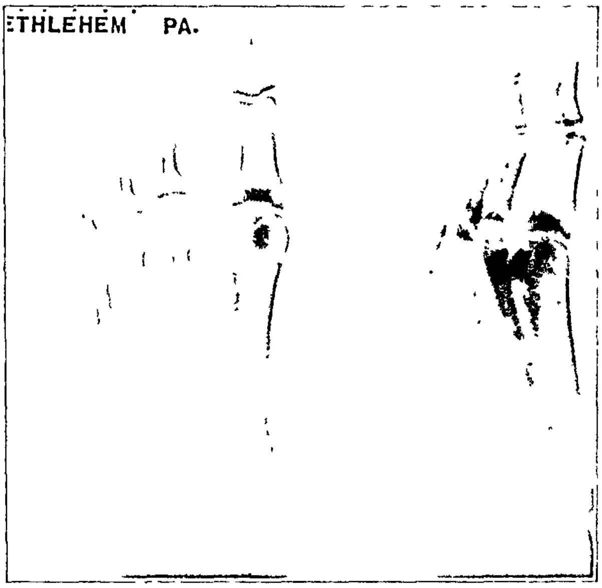
The six patients returning to work within ten days had mild damage to the soft parts. In three cases the fractures were simple; in the remaining three they were comminuted. In one of the cases of simple fracture, two metatarsals were involved. The ages varied from twenty-four to sixty-one years. In regard to occupation, two were engaged in heavy manual labor, one in light work, and the remaining three in skilled heavy work.

Eleven to Twenty Days

Of the six patients who returned to work in from eleven to twenty days, five had simple fractures involving one metatarsal, and the other patient had fractures involving two metatarsals. Two of the five single fractures were displaced. The soft tissue was in good condition in all cases. The patients' ages varied from twenty-four to fifty-five years. Two were engaged in heavy labor and four in skilled work.

Twenty-One to Thirty Days

The fractures in this group of seventeen cases varied from simple transverse fracture of one metatarsal (one case), two metatarsals (five cases), or three metatarsals (one case) to oblique fractures in six cases and comminuted fractures in four cases. Injuries to th soft parts varied from contusions (eight cases) and moderately swollen ecchymotic fee (four cases) to severe damage (five cases). All of the men were engaged in skilled work except four who were employed in heavy manual labor; their ages ranged from twenty-fou to fifty-five years, with an average of thirty-two years.



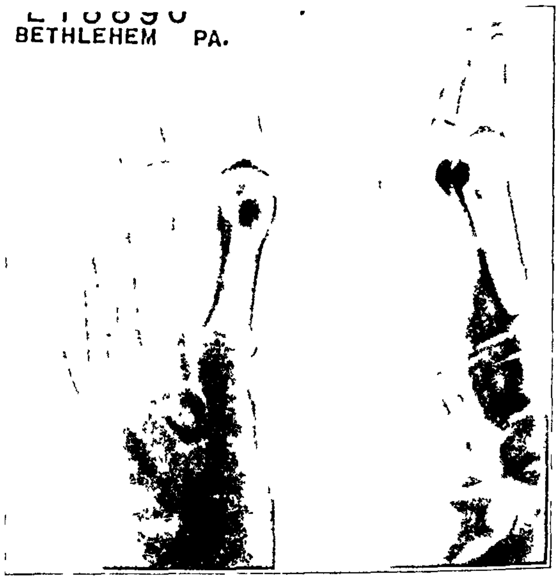
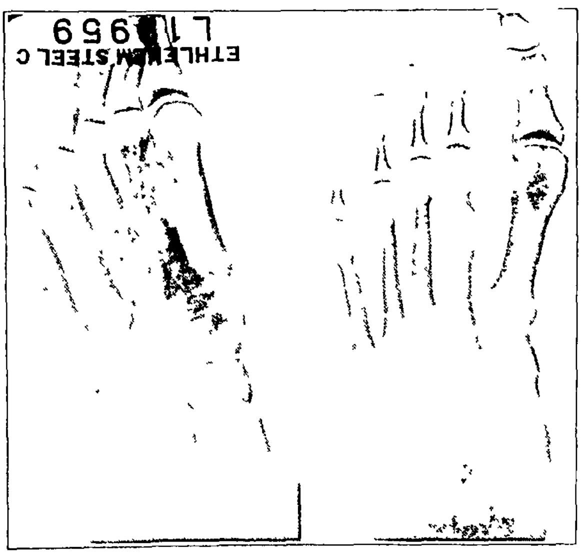


FIG. 7-A FIG. 7-B

L. D., aged twenty-eight, sustained an oblique fracture of the distal end of the fifth metatarsal of his left foot on June 24, 1943 (Fig. 7-A). He was released for special work two days later, and resumed his regular work on July 20, with no symptoms. The end results were $A_3E_4F_4$. The rating of A_3 was given because of widening of the shaft of the fifth metatarsal, as shown in Fig. 7-B (May 2, 1944).



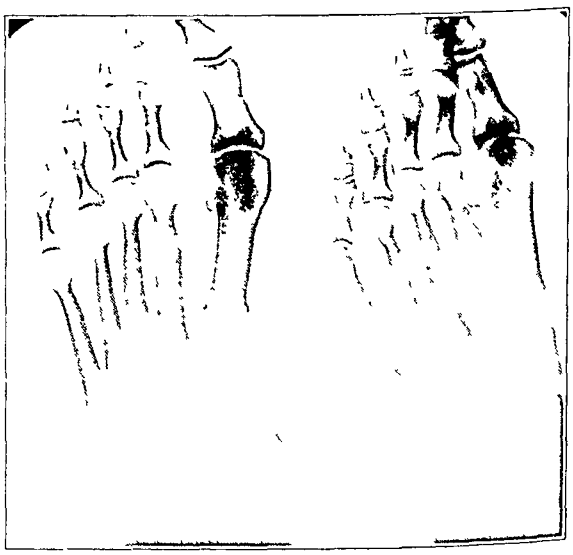


FIG. 8-A FIG. 8-B

L. B., aged thirty-two, fractured the second metatarsal of his left foot on March 3, 1944. He returned to his regular work the same day. The final rating was $A_3E_4F_4$. The rating of A_3 was given because 25 degrees of angulation was seen in the anteroposterior roentgenograms taken on June 15, 1944 (Fig. 8-A) and May 15, 1946 (Fig. 8-B).

TABLE IV

Anatomical, Economic, and Functional Evaluation of Results in Sixty-One Patients

Rating	Number of Cases	Per Cent.
$A_4E_4F_4$	57	93.5
$A_3E_4F_4$	4	6.5
Totals	*61*	*100.0*

Thirty-One to Forty Days

Of the fourteen fractures in this group, seven were fractures of a single metatarsal. Five of these had the following complications: arthritis involving the proximal joint, ankle sprain, impaction with 50 per cent. apposition, and a compound fracture. Six cases involved two metatarsals, and in the remaining case three metatarsals were involved. The soft parts were in good condition in two cases, six had mild involvement, and the remaining six had severe involvement. Four of the men were engaged in heavy manual labor, nine in skilled labor, and one in light routine labor. Their ages varied from twenty to fifty-eight years.

Forty-One to Fifty Days

In all but one of the eight fractures in this group, either multiple metatarsals were involved or there were complicated fractures to a single metatarsal. The complications were arthritis, which flared up, and severe injuries to the soft parts. In four cases only one metatarsal was involved; two patients had involvement of two metatarsals. and two had involvement of three metatarsals. The soft parts were in good condition in two cases; in two they were mildly impaired; and in the remaining four they were severely impaired. As in the previous group, four patients did heavy manual labor; the other four were skilled laborers.

Fifty-One to Sixty Days

The three fractures in this group were as follows: The first patient had impacted fractures of the necks of four metatarsals (the second, third, fourth, and fifth), with severe soft-tissue damage. The second patient had a fracture of the middle third of the second metatarsal, with severe soft-tissue damage. The third case was one of transverse fracture of the proximal third of the fifth metatarsal, with slight soft-tissue damage.

From the foregoing data, the following deductions can be drawn:

1. The age of the patient played no part in the individual's early return to work. In the range from twenty to sixty-one years, there seemed to be no marked difference in rapidity or amount of bone repair.

2. Except for two office workers, the man's occupation did not markedly affect his early return to work.

3. Condition of the soft parts and multiplicity of the metatarsals involved had the most direct effect on prolongation of the length of time spent by an individual on selected work.

FOLLOW-UP STUDY AND END RESULTS

Follow-up roentgenograms were taken six months after injury.

Final evaluation of the efficacy of this treatment, made from an anatomical, economic, and functional standpoint, showed excellent end results (Table IV). The method of rating is that used by the staff of the Fracture Service of the Massachusetts General Hospital [5].

Rating in each case is based upon three factors,—the anatomical (A), the economic (E), and the functional (F). The numbers used after each letter range from four to zero, inclusive. Four denotes an end result of from 87.5 per cent. to 100 per cent.; three from 62.5 per cent. to 87.5 per cent.; two from 37.5 per cent. to 62.5 per cent.; one from 12.5 per

cent. to 37.5 per cent.; and zero anything below 12.5 per cent. The highest possible rating is thus $A_1E_1F_1$.

The anatomical result was determined by the alignment and apposition of the fragments, as revealed by roentgenograms; the functional result by examination of the range of motion in the articulations adjacent to the fracture, the muscle power, and freedom from pain, including symptomatology of the longitudinal and transverse arches; and the economic result by the patient's earning power,—whether he was able to return to his former job or to earn as much as he had previously.

SUMMARY

It is felt that the application of this simple treatment accelerated the return of men to active work and reduced to a minimum the days lost. Had the accepted plaster-of-Paris method of treatment been used in these cases, the average period of disability would have been six weeks, with a probable total loss of 2,772 man-days, as compared with the 132 days lost in this series. In addition, the psychological effect of not having to wear a cast helped the injured man to justly minimize his injury and encouraged him to use his injured foot more freely, thus maintaining good circulation and hastening bone repair.

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ARTHROPLASTY OF THE TEMPOROMANDIBULAR JOINT IN CHILDREN WITH INTERPOSITION OF TANTALUM FOIL

A Preliminary Report

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Ankylosis frequently recurs after arthroplasty of the temporomandibular joint in children, and this has always been disappointing. In performing the arthroplasty by the accepted methods, fascia has been the usual intervening material inserted to secure a false

Fig 1-A

Fig 1-B

Fig 1-A Normal left temporomandibular joint
Fig 1-B Ankylosed right temporomandibular joint, before operation

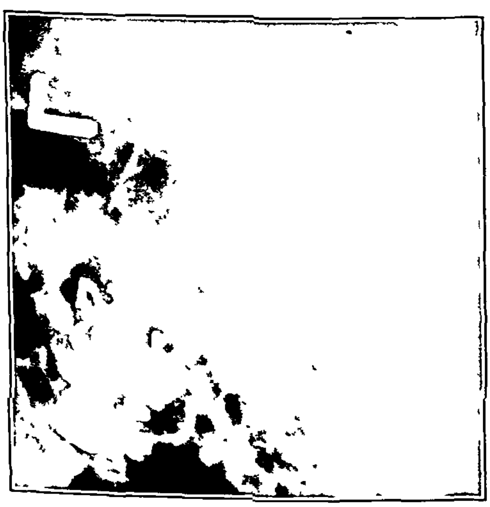

Fig 2-A

Fig 2-B

Fig 2-A Normal left temporomandibular joint
Fig. 2-B Right temporomandibular joint, with tantalum foil in position

Fig. 3
Postoperative roentgenogram of arthroplasty.

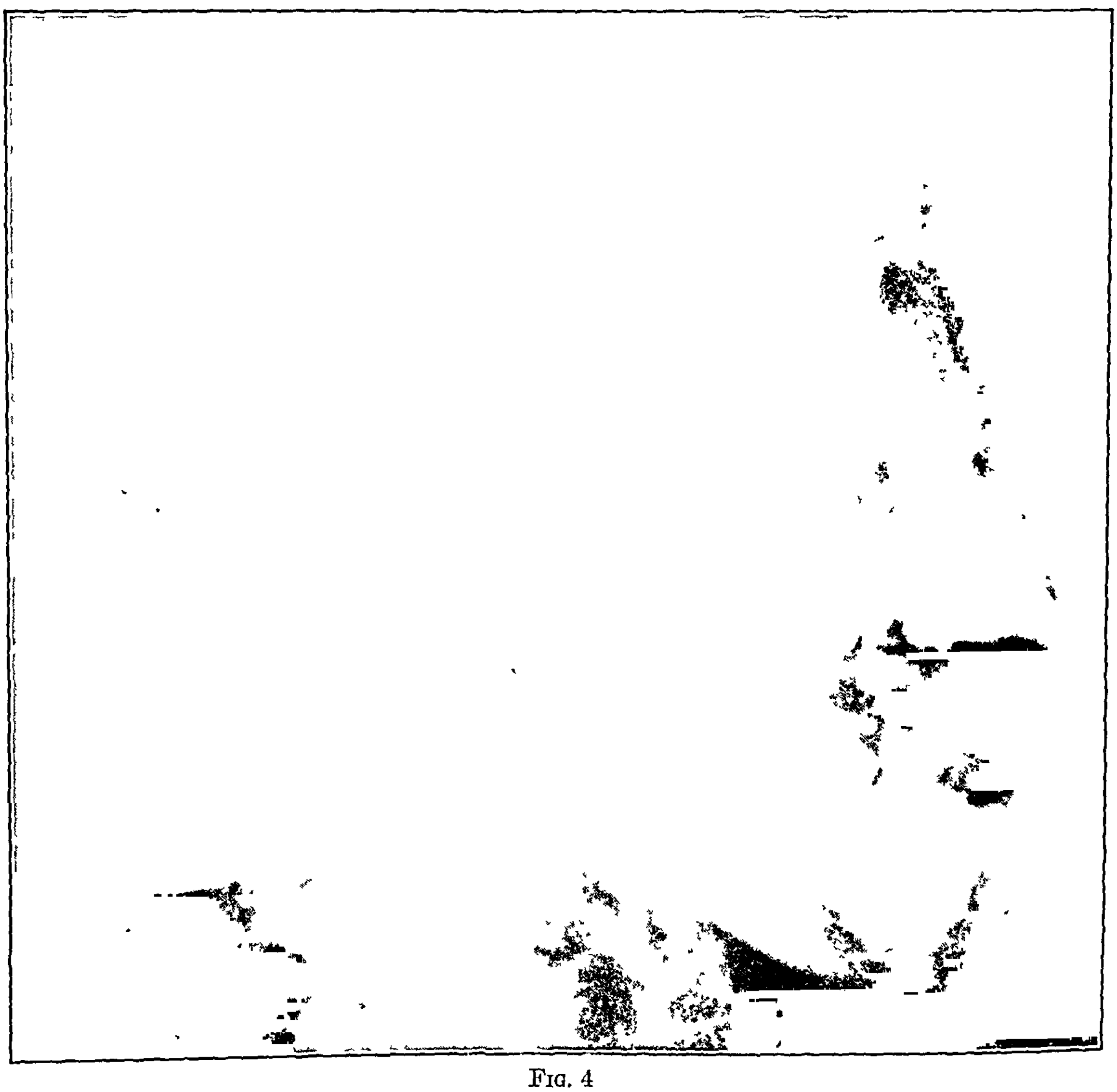

Fig. 4
Mandibular excursion, one year after operation.


FIG 5-A FIG 5-B
Result one month after operation


FIG 6-A FIG 6-B
Functional result, thirteen months after operation

joint. The technique of arthroplasty of the mandible will not be considered in this discussion, but rather the prevention of recurrence of the ankylosis.

A study of the recurrent case usually reveals bridges of bone from the mandible to the base of the skull, and, although the line of the false joint is evident, a firm union is slowly being created. The osteogenetic activity which occurs in these children is unfortu-

nate. In many cases the fusion is so extensive, in proportion to the size of the mandible and the age of the child, that the surgeon has a real problem to cover the denuded bone surfaces, after the ankylosis has been relieved. Mandibular pressure on the joint is very great in children, and probably is a factor in destroying the intervening fascia.

To overcome this fascial disappearance, it was decided to use a more lasting material, and tantalum was selected. The thin foil is cut considerably larger than the denuded bone surface, folded, and placed over the exposed bone surfaces. One piece is placed over the base of the skull and a second piece, similarly cut and folded, is placed over the mandibular portion, particularly down the medial side. Thus there are four layers of tantalum foil between the bone surfaces. It is a bit brittle and cracks, but satisfactory coverage can be secured and even small pieces can be packed in areas where intervening material is desired. It cannot be fastened with sutures, but the mandibular pressure packs the tantalum foil firmly against the denuded bone and creates an area which discourages osteogenesis and the recurrence of ankylosis.

CASE REPORT

C.L.C., a four-year-old white girl, was first examined in December 1944. The history revealed that in 1940 the patient had had acute mastoiditis of the right side, for which a radical mastoidectomy had been performed. She had had a rather stormy course, and about forty days after operation she began to have difficulty opening her mouth. This became so severe that a local physician gave the child a general anaesthetic and opened the mouth forcibly. In a short time, however, she again could not open her mouth, and the right cheek became more prominent than the left. During the past several years, the mouth had been opened forcibly about twenty times. At the time of examination, the patient was unable to open her mouth.

A roentgenographic study disclosed extensive ankylosis of the right temporomandibular joint (Fig. 1-B). The left temporomandibular joint was normal (Fig. 1-A).

On January 6, 1945, an arthroplasty of the right mandible was performed; tantalum foil was used as the intervening material between the denuded bone ends (Figs. 2-B and 3). Four weeks later the function of the jaw was satisfactory (Figs. 5-A and 5-B).

Roentgenograms taken a year later show satisfactory excursion of the patient's mandible (Fig. 4). Photographs taken thirteen months after operation show the functional result of the arthroplasty (Figs. 6-A and 6-B). There was no evidence of increasing rigidity of the mandible to indicate future restriction of motion.

GUNSHOT WOUNDS OF THE MAJOR JOINTS

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Among the most serious of all war injuries of the extremities are gunshot wounds of the major joints. Treatment of these injuries is usually difficult and the results are often disappointing. Disability of some degree—due to chronic arthritis, instability, fibrous or bony ankylosis, and associated nerve injuries—occurs in a high percentage. Septic arthritis, which is a frequent complication, often endangers life.

Concerning the treatment of joint wounds, there is notable difference of opinion, probably because the results following any method of treatment are so often discouraging. Fruchaud has stated that many French surgeons favor leaving the joint widely open at the primary operation, while the British usually prefer closure of the capsule whenever possible. During a visit to Russian hospitals, Watson-Jones found that the Russians have advocated early, complete excision of acutely infected knee and hip joints in preference to arthrotomy. Sir Anthony Bowlby, after a wide experience with joint injuries, advised amputation for comminuted fractures of the femoral condyles with involvement of the knee joint; this suggestion would probably be accepted by few American surgeons.

During World War II, the authors have seen very few reports by American military surgeons of gunshot wounds of the joints. Experience with these injuries at a General Hospital in India during the North Burma Campaign has been reviewed. In caring for a large number of Chinese patients, whose treatment was necessarily carried to completion before discharge in most instances, it has been possible to observe all phases of treatment, including the late reconstructive stages of arthroplasty and arthrodesis.

ANALYSIS OF CASES

This series comprises 134 wounds of the major joints in 133 patients. Table I gives their distribution. Wounds of the knee joint were the most frequent, constituting 57 per cent. of the total. The injuries were equally distributed as to the side of the body, with the exception of shoulder and hip wounds, in which the right shoulder and the left hip predominated.

TABLE I

DISTRIBUTION OF 134 INJURIES OF MAJOR JOINTS

Joint	Right	Left	Total	Per Cent. of Total
Hip	3	8	11	8.2
Knee	38	39	77	57.5
Ankle	6	7	13	9.7
Shoulder	10	2	12	8.9
Elbow	10	11	21	15.7
Totals	67	67	134	100.0

Eighty-six per cent. of the wounds were in Chinese soldiers, and 14 per cent. in American soldiers. Since almost all of the Chinese patients were kept in this Hospital during the entire course of treatment, the final results are known in most instances. Several American patients were evacuated to the Zone of the Interior before the outcome could be ascertained.

The North Burma Campaign has been called a "small-arms" war. Almost half of the wounds were caused by bullets of twenty-five caliber, and the remainder by shell fragments,—usually mortar. Undoubtedly the wounds were less severe than those in theaters

TABLE II

SUMMARY OF DEFINITIVE TREATMENT

Treatment	Hip	Knee	Ankle	Shoulder	Elbow	Total	Per Cent of Total
			Immobilization				
Plaster	9	71	13	12	21	126	94.0
Traction	2	6	0	0	0	8	6.0
			Local Medication				
Sulfanilamide	All	All	All	All	All	134	100.0
Chlorazene	5	12	1	1	1	20	15.0
Penicillin	5	5	1	1	1	13	9.7
			General Medication				
Sulfonamides	All	All	All	All	All	134	100.0
Penicillin	7	11	1	1	4	24	18.0
Transfusions of whole blood	10	19	2	0	2	33	24.6
Plasma transfusions	4	1	0	0	1	6	4.5
			Operative Procedures				
Secondary débridement	0	2	2	0	2	6	4.5
Removal of foreign bodies	2	10	1	1	2	16	12.0
Aspiration	0	15	0	0	0	15	11.2
Incision and drainage	9	20	4	2	2	37	27.6
Amputation	0	1	0	0	0	1	0.7
Early joint resection	0	3	0	0	0	3	2.2
Manipulation under anaesthesia	1	3	0	2	2	8	5.9
Late operative fusion	0	5	0	4	3	12	8.9
Arthroplasty	1	0	0	0	0	1	0.7

of operation where more destructive missiles prevailed. Fifty-four per cent. of the wounds were penetrating and 46 per cent. were perforating.

Fracture of adjacent bone complicated the joint wound in 75 per cent. of the cases. In the remaining 25 per cent. (twenty-seven wounds of the knee and seven of the elbow), there was no associated fracture.

In fourteen instances (10.4 per cent.) there was an associated nerve injury, with the following distribution:

Shoulder	
Axillary nerve	1
Elbow	
Radial nerve	3
Ulnar nerve	3
Median nerve	1
Hip	
Sciatic nerve	4
Knee	
Peroneal nerve	2

Débridement was carried out in portable surgical hospitals in 96 per cent. of the patients. The adequacy of the débridement varied considerably. In approximately one third there was a record of closure of the capsule; in many the capsule could not be closed because of the extent of the wound. Following débridement, sulfanilamide was applied locally to every wound. In only one instance was the skin closed primarily; in the remainder the wound superficial to the capsule was held open with vaseline gauze. Prophylactic sulfonamide therapy was begun orally soon after injury, for penicillin was not available at any time during this Campaign in the forward installations. Circular plaster was used to immobilize the joint during evacuation in almost every instance.

The average interval before admission to this Hospital after being wounded (following

TABLE III

Complications Observed in 90 of the 134 Joint Wounds

Complication	Hip	Knee	Ankle	Shoulder	Elbow	Total	Per Cent. of Total Wounds
Septic arthritis	9	20	7	4	5	45	33.6
Osteomyelitis	8	11	5	4	1	29	21.6
Soft-tissue abscess	2	4	0	0	0	6	4.5
Anaerobic cellulitis	0	2	0	0	2	4	3.0
Septicaemia	0	1	0	0	0	1	0.7
Secondary hemorrhage	1	0	0	0	0	1	0.7
Thrombophlebitis	2	0	0	0	0	2	1.5
Volkmann's contracture	0	0	0	0	1	1	0.7
Sudeck's atrophy	0	0	1	0	0	1	0.7
Totals	22	38	13	8	9	90	67.0

a litter haul of varying distances and evacuation by air for more than 100 miles) was six days, although half of the patients were admitted within the first two days.

Treatment at this Hospital is summarized in Table II. The "closed-plaster" technique was used for the definitive treatment of more than 90 per cent. of the wounds. Continuous traction (balanced skeletal traction-suspension, with a Kirschner wire for transfixion) was used in only eight instances: two wounds of the hip and six of the knee. In all instances in which traction was used, there was an associated fracture, and traction was used primarily for treatment of the fracture.

Local and oral sulfonamides were used prophylactically in all patients. Penicillin was available only during the latter part of the Campaign, and then in very limited amounts. Of the twenty-four patients who received penicillin, it was used prophylactically in only two. Several chronically infected joints containing considerable necrotic material were irrigated at frequent intervals with a 1 per cent. solution of chlorazene. Anaemia and hypoproteinaemia were corrected as early as possible by transfusions of whole blood and plasma and by dietary measures.

An inadequate primary operation necessitated the secondary débridement of six wounds. Foreign bodies were present in sixteen joints on admission, and were removed as soon as practicable. Septic arthritis required incision and drainage in thirty-seven patients. There was only one amputation; this was performed because of gas gangrene following an injury to the knee joint. Three chronically infected knee joints were resected.

Complications and their incidence are shown in Table III; they occurred in ninety of the 134 joint wounds. Septic arthritis was the most frequent (33.6 per cent.) and the most serious complication. Osteomyelitis was two thirds as frequent, occurring in 21.6 per cent. of all the wounds (27 per cent. of the cases associated with a fracture). In one patient septicaemia developed, in spite of the prophylactic use of sulfonamides and penicillin. In this case the causative organism, *Bacillus pyocyaneus*, was resistant to sulfonamides and penicillin.

Anaerobic cellulitis without gangrene developed in four wounds, and was controlled by prompt surgery. There was only one instance of gas gangrene, and this necessitated amputation. The Volkmann's contracture was due to ischaemia, caused by constriction at the elbow by a tight, unsplit, unpadded plaster cast, used during evacuation.

There were three deaths in the series,—a mortality of 2.3 per cent. One was due to pulmonary embolism following incision and drainage of a hip joint for septic arthritis; an associated peritonitis caused the second; and the third was due to *Bacillus pyocyaneus* septicaemia, following a knee-joint wound with no associated injuries.

At present, 118 joints have been observed for a sufficiently long period to permit classification of the results, as shown in Table IV. In all likelihood, several of the joints with motion of less than 50 per cent. of normal at present will show further gradual improve-

ment, and may in time regain nearly normal function. Also, in some of the joints which now have fibrous ankylosis, bony ankylosis will eventually develop.

PRIMARY TREATMENT

Because of the vulnerability to infection of the synovial membrane and the articular cartilage, and the inevitable progressive damage caused by retained foreign bodies and unattached bone fragments, a thorough and painstaking primary débridement of joint wounds is imperative for good results. Emphasis must be placed primarily on the prevention of infection, for once infection has become established in a joint, its treatment is extremely difficult. If an early operation has not been possible, a delay of from one to several days is not a contra-indication to débridement, even in the presence of infection. In such instances the authors have been impressed with the value of excising devitalized tissue and removing foreign bodies in improving the chances for a good result.

If there is any doubt about the adequacy of the débridement or the removal of all foreign bodies, the capsule should not be closed. Suture of the capsule in the presence of devitalized tissue or foreign bodies may prove disastrous. If a thorough débridement is assured, closure of the capsule is advisable and is of value in the prevention of infection. In this series it has not seemed valid to compare the incidence of infection in joints with and without closure of the capsule, because in most instances in which the capsule was not sutured, the extent of the wound precluded closure. Such wounds were the most severe, with extensive damage to soft tissue and bone, and thus more likely to become infected. If the capsule cannot be closed, the joint should be carefuly protected from further infection by an occlusive dressing. Under no circumstances should gauze, rubber dam, rubber tubes, or other drainage material be placed within the joint cavity.

Since local and oral sulfonamides were used in the treatment of all of these wounds, it is difficult to appraise their value in the prevention of infection. It seems likely, however, that they have been responsible for the prevention of spreading infection and septicaemia in many instances. In the one case of septicaemia in our series, the causative organism, *Bacillus pyocyaneus*, was sulfonamide-resistant. Since penicillin has been shown to be active in the presence of blood, pus, and tissue autolysates, it should prove to be of much greater value than the sulfonamides in the treatment of joint injuries. Local and general penicillin therapy should be instituted as soon as possible after the patient has been wounded.

TABLE IV

FUNCTIONAL RESULTS IN 118 JOINT WOUNDS

Result	Hip		Knee		Ankle		Shoulder		Elbow		Total	Per Cent of Total
	(No.)	*(Per cent.)*	*(No.)*	*(Per cent.)*	*(No.)*	*(Per cent.)*	*(No.)*	*(Per cent.)*	*(No.)*	*(Per cent.)*		
More than 50 per cent. motion	1	16.6	45	62.5	2	18.1	2	18.1	8	44.4	58	49.2
Less than 50 per cent. motion	0	0	10	13.9	3	27.3	6	54.7	4	22.2	23	19.5
Fibrous ankylosis	0	0	8	11.1	3	27.3	2	18.1	3	16.7	16	13.5
Bony ankylosis	5	83.4	9	12.5	3	27.3	1	9.1	3	16.7	21	17.8
Totals	6	100.0	72	100.0	11	100.0	11	100.0	18	100.0	118	100.0

TREATMENT AT FIXED INSTALLATIONS

A. *General Treatment*

Almost all of these wounds were treated by the closed-plaster technique, which allowed the wound to heal by second intention. In more recent injuries, not included in this series, clean joint wounds have been closed between the fourth and tenth day after injury, as suggested by Churchill. It is especially important that joint surfaces be covered as soon as possible, by the apposition of overlying soft tissue. When there has been considerable loss of skin, the wounds should be dressed early with split-skin grafts.

The involved joints should almost always be immobilized in the position of election for fusion, unless treatment of an associated fracture requires another position. Even then, if infection is present, the position of election should be used in order to avoid ankylosis at an unfavorable angle.

The early use of massive transfusions of whole blood has appeared to be of value in the prevention of joint infection. Once septic arthritis and anaemia coexist, the amount of blood necessary to restore the hemoglobin to normal is multiplied many times.

Internal skeletal fixation of a compound battle fracture is hazardous and almost always unnecessary. It is so important in the joints of the lower extremities to restore the normal weight-bearing alignment and to assure a normal axis of rotation, however, that fixation of large displaced articular fragments with bolts, screws, or pins seems justified, if closed methods are not successful. Systemic chemotherapy increases the safety of this procedure.

B. *Septic Arthritis*

If there are any symptoms or signs of infection on admission to a fixed installation, the wound must be inspected without delay. Drainage of an infected joint at the earliest possible moment is essential, if the joint is to be salvaged. Aspiration and irrigation with penicillin solution may eradicate infection in a small number of early cases, but it is dangerous to delay incision and drainage unless the signs of infection clear rapidly. Drainage must be radical, for experience has taught that infection can be eliminated only if drainage incisions are adequate to provide exposure of all recesses of the joint and to permit dependent drainage. If drainage has not been thorough, additional pockets of pus are almost certain to form and a septic course ensues, with eventual joint destruction.

The clinical picture of a patient with chronic septic arthritis is impressive. This was especially notable in the Chinese. In walking through the Chinese orthopaedic wards, one could usually tell at a glance the patients with joint infection by their "septic-arthritis facies". The emaciation, the drawn and waxen face, the unusual listlessness, and the apprehension were in striking contrast to the usual healthy appearance of the fracture patient. The temperature chart was characteristic,—septic in type, with a normal morning level and an afternoon or evening rise to from 102 to 104 degrees.

Penicillin was available for use in half of the cases of septic arthritis. Systemic penicillin therapy almost always improved the general condition of the patient, but the results of the local application of this drug to chronically infected joints were disappointing. Emphasis must be placed on the early institution of adequate drainage. Chemotherapy is only an adjunct to thorough surgery.

Foreign bodies which have perforated a joint and have lodged in adjacent bone present a difficult problem. If they are allowed to remain, bacteria are continually fed into the joint through the sinus tract, and a chronic septic arthritis results. These foreign bodies should always be removed, unless such an operation necessitates the destruction of considerable bone or cartilage.

Coincident joint involvement significantly increases the likelihood of osteomyelitis in a compound fracture. Twenty-seven per cent. of the patients with compound fractures

in this series developed bone infection,—a much higher incidence of osteomyelitis than occurred during this Campaign in compound fractures not associated with joint involvement.

Although many of the Russians [11] advocate resection of the joints in all early cases of septic arthritis and others [10] advise early resection if there is an associated fracture, the authors believe that, if early and adequate drainage is established and chemotherapy is employed, many joints will be saved and excellent functional results obtained, even if a fracture is present. This was our experience with several septic knee joints in which incision and drainage were done early. In late cases, however, when infection has become chronic and there is evidence of joint destruction, resection of the joint is the procedure of choice. The use of systematic chemotherapy following this procedure is essential to prevent spreading infection and septicaemia.

C. *Nerve Injuries*

The infrequency of nerve injuries in this series was surprising, in comparison with other reports. Irwin and Bailey [1], for example, found associated nerve injuries in 95 per cent. of wounds of the shoulder joint, while there was nerve paralysis in only one out of twelve shoulder wounds in this series. The high percentage of small missiles, with less destructive wounds, may account for this.

An associated nerve injury often produces greater disability than the joint wound. It is now generally agreed that severed nerves should be repaired within the first few weeks after injury, if optimum regeneration is to be obtained. The surgeon responsible for treating the joint wound must cooperate with the neurosurgeon in accomplishing this. If nerve regeneration does not occur, the involved joints may be fused in the position of election, or tendon transplantations may be performed.

D. *Mobilization*

The optimum time for starting motion of an injured joint has always been a point of contention among surgeons. In many instances, the immobilization required for an associated fracture greatly lengthens the time required for the joint alone. It has been the practice of the authors to shorten the usual period of immobilization of a fracture, if a contiguous joint has been injured. Motion must never be started, however, until there is clinical evidence of union. In clean joint wounds not associated with a fracture, immobilization was continued for about two weeks after the temperature had become normal. Physical therapy was then begun. If motion caused a return of fever, the joint was again immobilized. In infected joints, immobilization was continued for three weeks after all signs of infection had cleared.

Continued, regular, painstaking, *active* motion was found to be the most helpful measure in improving joint function. Passive motion should never be carried beyond the point of pain. Manipulation under anaesthesia was disappointing in the eight instances in which it was tried; a painful joint with diminishing function was the usual result. The authors believe that forceful manipulation should never be employed in these injuries.

Wedge plasters, however, were productive of more beneficial results, especially in the Chinese patients, many of whom refused to practise active exercises. A circular plaster was applied, with strips of flannel incorporated on the lateral aspects of the joint for hinges; an elliptical segment of plaster was removed from the side toward which it was desired that the distal limb of the joint be moved; and, on the opposite side, the plaster was split through one-third of its circumference so that increasing numbers of wooden blocks could be inserted daily, after the joint had been moved through its entire range of motion several times. This method has been used by Kirk for the correction of flexion deformities of the knees, following leg amputations.

PROBLEMS RELATED TO SPECIFIC JOINTS

Hip

Wounds of the hip are undoubtedly the most serious of all joint injuries, and the most disappointing to treat. In the eleven hip wounds in this series there were two deaths; septic arthritis developed in all; bony ankylosis occurred in five; and more than 50 per cent. of normal motion resulted in only one. Three patients (all Chinese) are still in the Hospital, more than a year after injury. Such poor results are obtained because (1) the joint is deep lying and difficult to expose, which often prevents thorough débridement and makes adequate incision and drainage most difficult, once infection has been established: (2) the precarious blood supply to the head of the femur is often destroyed by the injury, which leads to necrosis; and (3) the incidence of associated intra-abdominal injuries and injuries to the sciatic nerve is high.

The authors believe, however, that even these results are better than would have been obtained if early resection or disarticulation had been done in all instances, as is advised by Molodaya. Had earlier and more extensive drainage incisions been used in this series, preferably through the posterior approach recommended by Ober, the results might have been better. In several of our cases, incision and drainage were done only after irreversible damage had occurred. Once infection has become chronic and destruction of the joint has begun, the joint should be resected and the head and neck of the femur removed. Girdlestone has described a technique for this. Two incisions are used: One is behind and below the anterior superior spine, and through it the gluteal muscles are divided; and the second is at the base of the greater trochanter. The trochanter and its attached tissue are removed *en masse* so that the glutei are included. The hip joint and head and neck of the femur are then excised. The hip should be immobilized in the position of election for fusion: 15 degrees of flexion, slight abduction, and the neutral position of rotation.

When continued suppuration occurs in a hip joint and there is extensive osteomyelitis of the proximal part of the femur, Harmon and Adams believe that disarticulation may be advisable. If this is indicated, one must not delay operation until the patient's poor general condition makes the operation excessively hazardous.

Many orthopaedic surgeons[7] advise continuous traction for the treatment of septic arthritis of the hip in civilian practice. Acceleration of cartilage destruction by pressure of contiguous joint surfaces, which occurs when plaster immobilization is used, may be eliminated, it is thought, by traction. These cases, of course, are rarely due to gunshot wounds, and do not have extensive bone and soft-tissue damage. Although traction was used in only one of our patients, it seems likely that this is the preferable method. Only a moderate amount of traction should be used, because of the danger of dislocation. In addition, care must be taken to prevent deformities of adduction and external rotation, which are prone to occur. This can be done by keeping the thigh adducted at all times.

Knee

Wounds of the knee joint were by far the most frequent in this series, and in this group there was the highest percentage of good results. The joints were immobilized in a position of from 5 to 10 degrees of flexion by a circular plaster from groin to ankle. If there is an associated fracture of the femoral condyles, a single hip spica should be used. Quadriceps exercises must be begun early.

If septic arthritis develops, early and radical drainage must be instituted. Long parapatellar incisions, which expose both sides of the quadriceps pouch, are necessary. The patient should spend a part of each day in the prone position to facilitate anterior drainage. When the posterior compartment is involved, posterior arthrotomy is necessary. If the infection becomes chronic and joint destruction has begun, resection of the joint eliminates infection, causes earlier fusion, and shortens convalescence. This was done in three of our patients, with excellent results in all instances.

When an infected knee joint is associated with a fracture of the femur, a position of

moderate flexion (routinely employed for femoral fractures treated by traction methods) must be avoided in order to prevent a persistent flexion deformity. Immobilization must be in a position of from 5 to 10 degrees of flexion.

Injury of the patella did not appear to predispose to a poor result in these cases. Of the ten wounds of the knee joint in which the patella was involved, a good functional result was obtained in all. The quadriceps tendon had not been divided in any, and suture was not necessary. The patella was removed in three instances and, following suture of the quadriceps tendon, a good functional result was obtained in two and a fair result in the third.

Ankle

Although in only two of the eleven wounds of the ankle joint was more than 50 per cent. of normal motion regained, disability from this injury was not great. Infection was less difficult to control than in wounds of the hip and knee, and did not produce such a severe toxic reaction. When the joint was ankylosed in 5 degrees of plantar flexion and in the mid-position of pronation-supination, a surprisingly good functional result was obtained.

Shoulder

All wounds of the shoulder joint should be immobilized in a plaster spica, with the arm abducted 40 degrees and a little anterior to the plane of the body. Fusion in this position gives a fair functional result with the aid of scapular motion, and is preferable to a painful shoulder with some motion.

Elbow

Next to wounds of the knee, elbow wounds showed the best functional results. Half of the patients have obtained more than 50 per cent. of normal motion at this time. Infection is easily controlled, as a rule. Because of the superficial location of the joint, drainage is not difficult and sequestra are easily removed.

Forceful manipulation is especially harmful in elbow injuries. Continued active exercise is the most useful method of improving function, which may gradually increase over a period of years.

The optimum position for ankylosis depends largely upon the occupation of the patient. In the Chinese soldier, the ability to feed himself was probably most important, and the elbow was fused in a position of hyperflexion, with the forearm in slight supination. In this position, the palmar surface of the hand is most easily brought to the mouth.

Buxton advises immobilization of suppurating elbow joints at a right angle, with the forearm in full supination; he maintains that in this position suppuration does not tend to spread along fascial or intermuscular planes. If ankylosis occurs, however, this position may not be optimum for the patient. It seems preferable to immobilize all suppurating joints in the position of election for fusion.

MORTALITY

Two of the three deaths were probably not preventable. One occurred in an American soldier, struck by a twenty-five caliber bullet, which perforated the left hip joint and rectum and emerged posterior to the sacrum. A laparotomy was done at a forward hospital, with negative findings. The patient arrived at this Hospital twenty-four hours after injury in desperate condition, with signs of overwhelming peritonitis, which caused his death. The other death was due to a pulmonary embolus, following incision and drainage of an infected hip joint on the eighteenth day after injury. The wound had not been debrided until four days after injury and the patient, a Chinese soldier, was admitted to this Hospital with severe septic arthritis.

The third death occurred in a Chinese soldier, who received a perforating bullet wound of the left knee twenty-four hours before admission. The wound had been debrided within three hours after injury, and appeared clean on admission. There were incomplete

fractures of the distal end of the femur and proximal end of the tibia, but no foreign bodies were present. Because of a septic condition and fever, he was given oral sulfadiazine and intramuscular penicillin; but incision and drainage were not done for seven days. This operation was not extensive enough, and the development of additional pockets of pus necessitated further incisions. Repeated blood cultures recovered *Bacillus pyocyaneus*. The septic condition continued, and the patient died on the twenty-eighth day after injury. Earlier and more thorough operation should undoubtedly have been done. When the infection did not respond to these measures, amputation might have been life saving. Had the causative organism, *Bacillus pyocyaneus*, not been resistant to the sulfonamides and penicillin, the infection could probably have been controlled.

RESULTS

The end results of joint injuries cannot be evaluated accurately unless the patient can be followed for several years. The remarkable improvement in several of the Chinese patients, examined at a rehabilitation camp about a year after injury, was very enlightening. The delayed improvement shown by these patients, and the relatively high percentage of good results in wounds of the knee and elbow obtained before discharge from this Hospital, lead to the belief that early amputation or early joint resection is rarely, if ever, justifiable.

CONCLUSIONS

1. One hundred thirty-four gunshot wounds of the major joints, treated during the North Burma Campaign, have been analyzed.
2. Disability of some degree—due to chronic arthritis, fibrous or bony ankylosis, and associated nerve injury—is relatively common.
3. The most important measure in the treatment of these injuries is early and thorough débridement. Closure of the capsule, after a thorough débridement, is probably helpful in preventing infection of the joint. If there is any doubt about the adequacy of the débridement or removal of all foreign bodies, the capsule should not be closed.
4. Septic arthritis, which occurred in one-third of these patients, is a serious complication. Early arthrotomy, with radical incisions to provide adequate drainage, will salvage many joints and is preferable to early resection.
5. Chronically infected joints, in which fusion is inevitable, should usually be resected.
6. Amputation for septic arthritis is rarely justified, but may at times be life saving.

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FRACTURES OF THE HEAD OF THE RADIUS

BY LIEUTENANT COLONEL JULIAN E. JACOBS AND CAPTAIN HAROLD B. KERNODLE

Medical Corps, Army of the United States

The relatively high incidence of fracture of the head of the radius, seen by the authors in the course of ten months, seems worthy of note. All fractures were the result of so-called minor accidents (falls from bicycles, ladders, or wings of planes, or simple falls during the black-out) sustained on various Army Air Corps bases in the vicinity. This fact has facilitated excellent follow-up studies.

INCIDENCE

In a ten-month period the authors have treated forty-two simple, acute fractures of the head of the radius. In this same period they have recorded ten simple fractures of the neck of the radius, three Colles's fractures and two Smith's fractures of the distal end of the radius, and 100 simple fractures of the carpal scaphoid. No complicated cases, such as those associated with dislocation of the elbow or Monteggia's type of fracture, are included in this series.

ANATOMY

Grossly, the head of the radius presents a type of bony structure similar to that seen in the patella, with the columnar type of dense cancellous bone running longitudinally. This explains the plane of the fracture, which is always longitudinal. The absence of periosteum about the head has been noted. The "ligamentum capituli radii" (as we have chosen to call the posterolateral continuation of the attachment of the quadrate ligament which is covered by a distinct fold of synovial membrane) is shown in the inset to Figure 1; and because at its base it envelops over a third of the circumference of the neck, it can be used at the time of operation (see section on *Surgical Technique*). The relationship of the annular ligament and the deep branch of the radial nerve is also shown.

The articulation of the head of the radius with the capitulum of the humerus is such

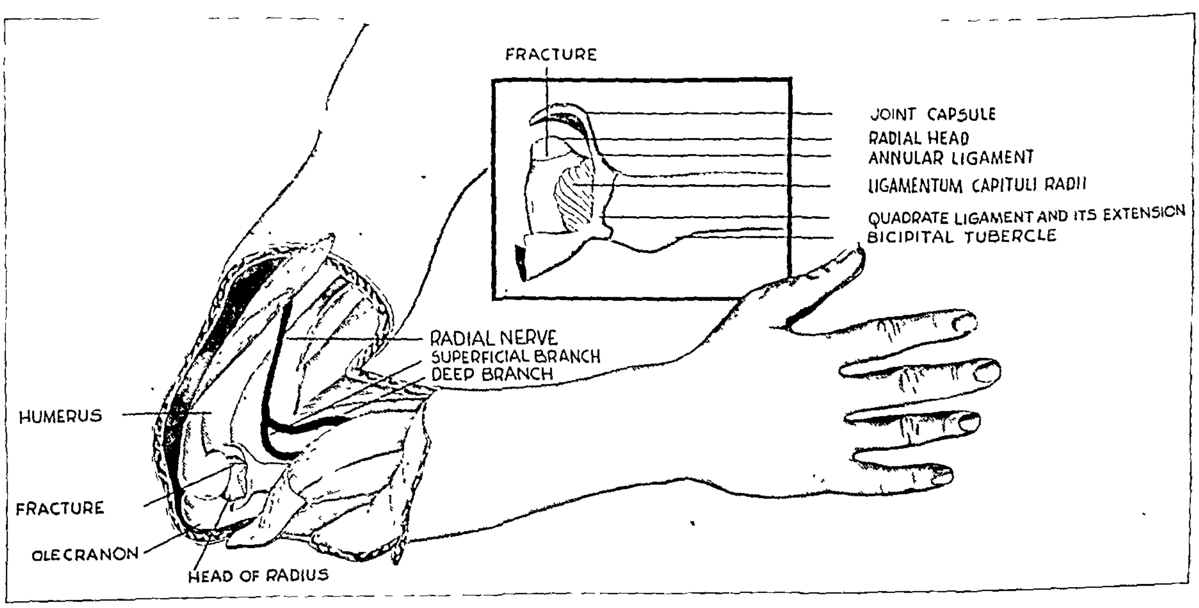

FIG. 1

Lateral view of the partially dissected right elbow joint, showing relationship of the radial nerve to the annular ligament. Inset shows the ligamentum capituli radii as a continuation of the quadrate ligament (from a dissected specimen, Cambridge University Medical School, Cambridge, England). Note relationship of bicipital tubercle to the fracture, with the forearm pronated.

that this joint acts primarily as a stabilizer at the elbow joint for abduction strains (pressure applied upward through the hand on the valgus elbow, with the carrying angle varying from 5 to 20 degrees). The head moves across the capitulum during flexion and extension of the elbow, but the actual rotation of the forearm on the ulna through approximately 120 to 160 degrees, by means of the articulation with the radial notch, demands approximately exact anatomical reposition of the fragments of the head in order to retain full supination and pronation.

TYPES OF INJURIES

Invariably the history in these cases is that of attempting to break a fall, either forward or backward, by taking the weight on the outstretched hand, with the elbow flexed slightly and the forearm partially pronated. This results in a cubitus valgus force, transmitted through the head of the radius to the capitulum of the humerus, fracturing the anterolateral segment of the head. This is shown in Figure 2, in which the fracture appears on the anteromedial side of the joint, with the hand partially pronated. The degree of leverage and the resulting angle at which the capitulum is driven into the pronated head of the radius determine the degree of comminution and displacement.

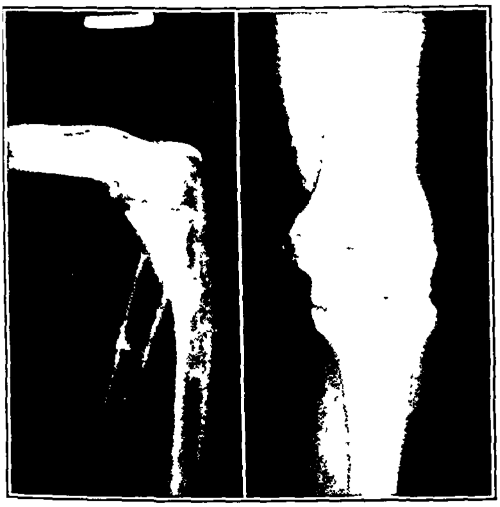

Fig. 2

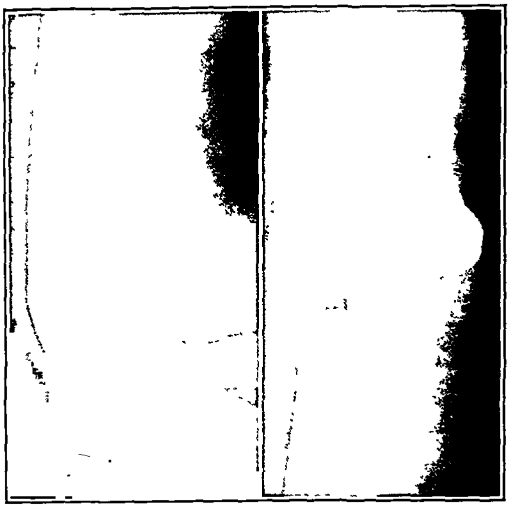

Fig. 3

Fig. 2: Type I fracture with forearm in pronation (the position at time of injury), showing relationship of the fractured segment to the capitulum of the humerus.

Fig. 3: Type I cleft fracture. Note persistence of fissure ten months after injury.

The associated trauma to the capitulum is not frequently seen roentgenographically, but it is often seen surgically. Late changes of the capitulum and lack of bony repair of the crack fracture of the head of the radius (Type I) are shown in Figure 3. That the abduction force also injures the medial portion of the capsule is shown by the fact that, even late in the follow-up, the patient will in some cases complain of discomfort about the medial aspect of the elbow joint.

TYPE OF FRACTURE

Fractures of the radial head have been divided into three classes. Type I includes the mild case with a simple crack fracture (chisel type or cleft fracture), in which a brief abduction force is applied to the anterolateral segment of the head against the capitulum of the humerus (Fig. 2). This results in either a single cleft across the head longitudinally, without depression (Fig. 3) or with slight depression (Fig. 4), without actual increase in circumference of the head. This type does well with conservative therapy.

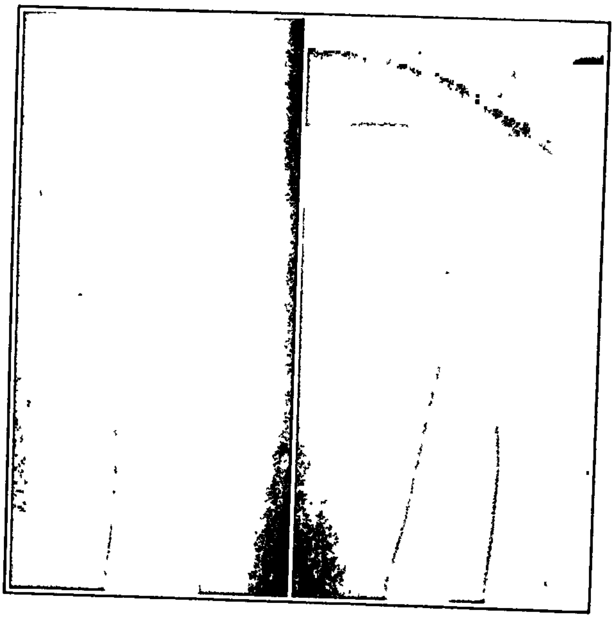

Fig. 4

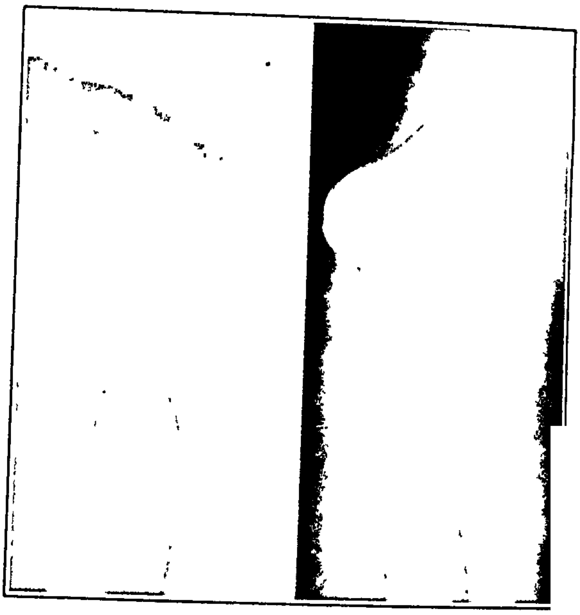

Fig. 5

Fig. 4: Type I cleft fracture, with slight depression of the anterolateral segment.
Fig. 5: Type II fracture, with comminution and some displacement.

Fig. 6

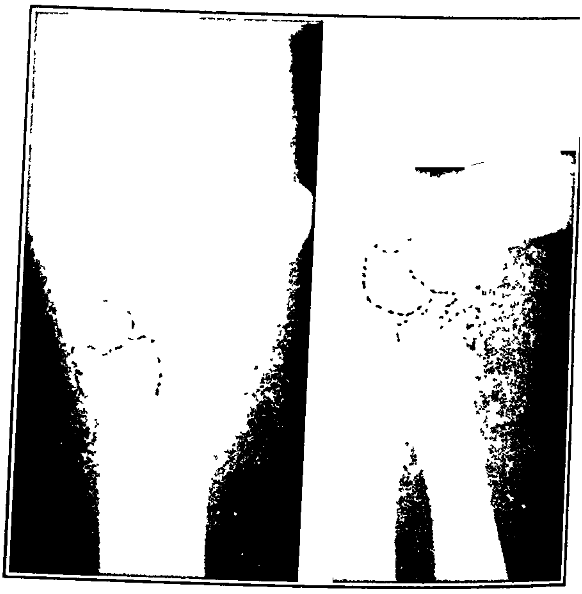

Fig. 7

Fig. 6: Type III fracture, showing severe comminution of the entire head of the radius.
Fig. 7: Type III fracture, showing severe comminution with displacement.

Type II comprises those fractures in which the circumference of the head has been increased moderately by comminution or disturbed by marginal displacement of the anterolateral segment (Fig. 5). The question of surgical excision most frequently arises in the treatment of this group; we feel, however, that all of these cases should be treated conservatively.

Type III includes those fractures with marked displacement of one or more bony fragments (Fig. 7). The authors feel that all of these cases should be treated by early surgery.

TREATMENT

Conservative treatment in the first type of fracture means merely the use of a sling, with or without aspiration of fluid from the elbow joint. Aspiration is indicated when the joint is tense, and had best be done twenty-four hours after injury, at which time the

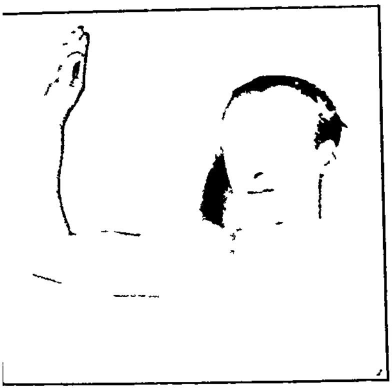

Fig. 8-A

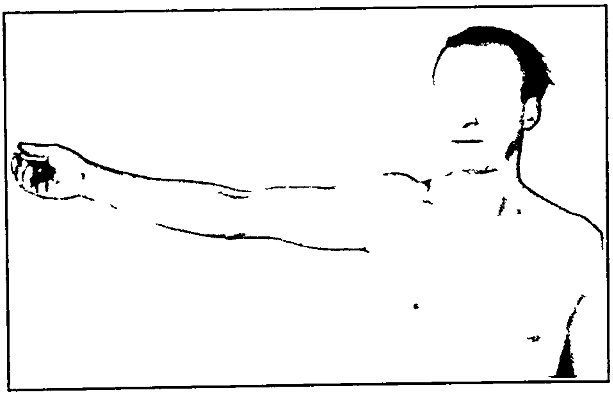

Fig 8-B

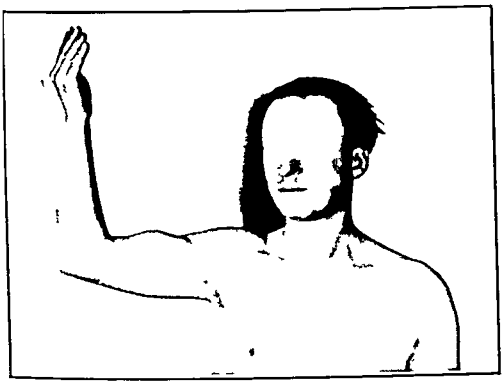

Fig. 8-C

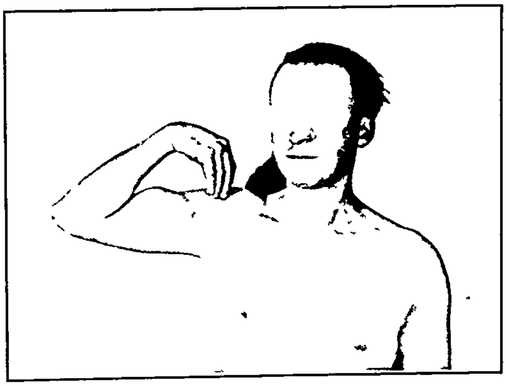

Fig 8-D

Patient with Type III fracture, six months after operation. Show full range of painless motion.

active bleeding usually has ceased. This procedure may have to be repeated. Relief of pain is quite remarkable, and the patient is thus encouraged to begin earlier motion. The use of a sling for a week or ten days adds to the comfort.

Conservative therapy in the second type of case consists of the treatment just mentioned or, in the more comminuted type, a period of ten days to two weeks in a plaster splint with the elbow at right angles and the forearm in neutral position. This is followed by a sling and active motion, with physical therapy, consisting of heat and mild massage daily. In two of the patients in this group, aspiration was done, and no difference was noted in the end results.

The third type is treated by early surgical excision of the entire head. The authors believe that surgery in the first week offers the best chance for the initial healing of these injuries. It saves the patient's time, and the joint can resume its function early. On several occasions the decision was made preoperatively to remove only the small fragment demonstrated roentgenographically, but so much comminution was found at the time of operation that the entire head was resected.

SURGICAL TECHNIQUE

The surgical technique consists of a lateral incision; a sphygmomanometer cuff, set at 200 millimeters of mercury, is used as a tourniquet. The incision extends from the lateral epicondyle through the conjoined tendon of the extensor digitorum communis and the extensor carpi ulnaris muscles. This incision is about two inches long and extends down to, but not beyond, the annular ligament. Care should be taken not to cut or to injure the deep branch of the radial nerve by traction on the mass of supinator muscle. Adequate

exposure of the joint can always be obtained by going to, or proximal to, the epicondyle. Inspection of the lateral joint space will invariably demonstrate much more comminution of the head than was visualized by roentgenogram, and will also reveal the trauma to the cartilage of the capitulum of the humerus. With the forearm fully pronated, the triangular ligament, referred to in the section on *Anatomy* as ligamentum capituli radii, comes into full view through the incision. Its relationship to the bicipital tubercle and to the fracture is shown in Figure 1, and has been confirmed at the anatomy table. By means of an osteotome, the ligamentum capituli radii is stripped down to where it blends with the synovial reflection, which offers a flap that can be sutured across the raw stump. A stump with a smooth neck can be obtained by using a sharp osteotome, held rigidly at the base of the head, proximal to the annular ligament. Frequent light tapping, together with rotation of the forearm through its 150 degrees, will leave a smooth cut instead of the minute bony fragments which result from the use of a Gigli wire. Any shredding of the cartilage over the capitulum is now pared down, and further inspection of the lateral joint compartment is readily performed. The humero-ulnar joint is visualized, and any interposing fragments can be removed. The previously reflected ligamentum capituli radii is now sutured across the smooth neck, covering it completely. The synovial membrane and the capsule are closed as one layer, the split conjoined tendon as another, and the skin as the third layer. Dressings, sterile sheet wadding, and a plaster cast, which holds the arm flexed to 90 degrees and the forearm in neutral position, complete the procedure. After two weeks the cast and the skin sutures are removed and active motion is begun, encouraged by physical therapy. The sling is discarded after two weeks, and the patient is ready for light duty at the end of four or five weeks.

END RESULTS

In this series of forty-two cases, twenty-eight (66.6 per cent.) were Type I, five (12 per cent.) were Type II, and nine (21.4 per cent.) were Type III. Twenty-two (52.4 per cent.) involved the head of the left radius and twenty (47.6 per cent.) involved the right. Thirty-three cases were treated conservatively and nine cases were treated by surgical excision. Table I shows the three types and the clinical findings.

Of the thirty-three cases treated conservatively, eight (24.2 per cent.) demonstrated

Fig. 9

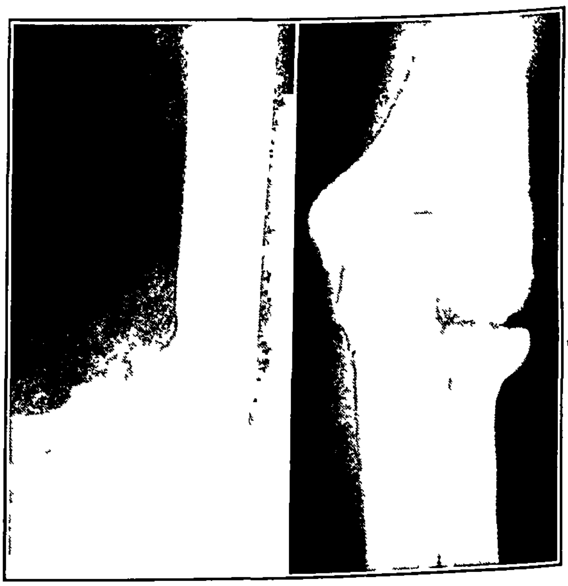

Fig. 10

Fig. 9: Resected radial head, six months after operation. Note absence of any bone reaction.
Fig. 10: Type I fracture, showing roughening of the capitulum humeri and lack of bony repair of the cleft. (Patient had history of "sprain" one year before.)

TABLE I

CLINICAL FINDINGS IN THREE TYPES OF FRACTURE

Type of Fracture	Patients with Normal Range of Painless Motion	Patients with 5 to 10 Degrees of Limitation in Extension and Supination		
		Without Pain	With Discomfort in Extremes of Motion	With Discomfort in Extremes and Tender Medial Joint
I	9	13	3	3
II	1	2	0	2
III	7	2	0	0
Totals	17	17	3	5

minimum limitation of motion, with discomfort in attempts at full supination or full extension. This was not severe, as none of the patients reported back to the clinic with this complaint. In contrast, when checked at the end of six months, none of the patients operated upon had any discomfort and actually showed a better range of motion (Figs. 8-A to 8-D) than some of the patients who had not been operated upon.

Bony spurs and myositis ossificans were absent in this series of cases. The cleft in the Type I cases persisted without any evidence of bone repair, even after ten months and a year, respectively (Figs. 3 and 10).

Temporary palsy of the radial nerve developed in one patient postoperatively as a result of the sphygmomanometer cuff, but recovery was complete in seven weeks. No symptoms about the wrist developed in any case.

DISCUSSION

This study has presented several problems. The limitation of motion (with or without pain) in the patients who were not operated upon has been attributed to the radial head; and yet, after surgical excision (either early or late), this limitation of motion was not altered in some cases.

Reference to the medial portion of the joint in the form of discomfort about the capsule was observed in three cases of Type I and two cases of Type II. This was explained on the basis of the abduction strain placed on this side by the initial trauma; and yet those patients of Type III with a similar, but usually more severe, abduction strain on the medial capsule did not complain. This was explained on the basis that the force was dissipated by collapse of the head. Late roentgenograms disclosed no bony disturbance in this region (Figs. 3 and 10). The question is occasionally raised of pain referred to the wrist, secondary to these fractures. We saw no such cases in this series, but have had the occasion, repeatedly, to observe the absence of clinical or roentgenographic evidence of trauma to the distal portion of the radio-ulnar joint. This seems best explained as referred pain. The innervation of the wrist joint by the terminal branches of the deep branch of the radial nerve, irritated in the region of the head of the radius, seems logical.

The question of support and rest of the part with the use of a plaster splint, which was used in two of the Type II cases because they seemed to be more severe, was answered when they were followed up. These patients did as well as those who were treated by the sling method.

Subsequent roentgenographic studies have shown no cases of osteochondritis dissecans involving the elbow joint, but Figure 10 presents evidence of the trauma to the capitulum humeri. The absence of any attempt at repair of the cleft type of fracture (Type I) is best explained on the basis of an intra-articular fracture.

Of the patients in Type III upon whom operation was performed, the absence of bony spurs about the stump of the neck of the radius is probably due to the method described for covering the stump.

SUMMARY

1. A series of forty-two cases of simple fracture of the head of the radius is presented, in which thirty-three cases (Types I and II) were treated conservatively, with excellent end results in 75 per cent. The remaining 25 per cent. showed a mild degree of disability.

2. Nine cases (Type III) were treated by total excision of the head of the radius, with excellent end results.

NOTE: The authors wish to express their thanks to Professor H. A. Harris and his staff of the Anatomy School at Cambridge University, Cambridge, England, for assistance.

A CASE RESEMBLING HEMANGIOMATOSIS OF THE LOWER EXTREMITY

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From the Department of Orthopaedic Surgery of the Hospital of the University of Pennsylvania, Philadelphia

The case recorded here presents a problem in diagnosis. A report of a similar case has not been found. The microscopic picture of the lesion suggests that it involves the capillary system, and the title was selected for this reason. On gross examination, however, no extraneous blood vessels were encountered. Although both bone and soft tissue were involved, the primary lesion appeared to surround the great vessels of the limb.

Irradiation was tried empirically. The favorable response has led the roentgenologist to feel that the lesion may be some type of malignant radiosensitive tumor. Microscopic examinations show no such evidence, however.

CASE REPORT

C. P., an eleven-year-old white boy, was in his usual state of good health until April 1941, at which time he fell from his bicycle and hurt his left knee. The region of the knee joint became swollen and

FIG. 1

Roentgenograms taken on April 17, 1942, show a lesion which involves the distal third of the femur. There is marked soft-tissue swelling. Destructive changes of lower third of femur do not involve the epiphysis. A pathological fracture is present.

FIG. 2

Microscopic section of femur shows osteoporosis of bone. There is a sprouting of capillary blood vessels, which is most evident where the trabeculae are thin and widespread.

discolored, and it was warmer than the other knee. He was treated conservatively by his doctor and in ten days was walking about with no pain, but the swelling and discoloration did not subside.

In May 1941, roentgenograms were taken because the swelling persisted. They showed no pathological changes of the bone. Roentgenograms were taken again in July, because the swelling and discoloration appeared to be increasing. Again no involvement of the bone was revealed.

It was then noted that the swelling and discoloration were spreading gradually above and below the knee. In February 1942, while turning over in bed, the patient experienced pain for the first time since the onset of his illness. After this, swelling soon involved the thigh and the upper half of the leg.

In April, he was admitted to the Orthopaedic Service of the Hospital of the University of Pennsylvania. His temperature, pulse, and respiration were normal. He was pale and undernourished. The left lower extremity was involved in a generalized swelling. The regions above and below the knee were discolored, and the skin temperature was elevated. A fluctuant wave, involving the thigh and the upper half of the leg, could be demonstrated. All arterial pulsations were normal.

The laboratory studies were as follows:

Hemoglobin	80 per cent.
White blood cells	7,500
Polymorphonuclear neutrophils	54 per cent.
Lymphocytes	32 per cent.
Monocytes	5 per cent.
Eosinophils	7 per cent.
Basophils	2 per cent.
Blood calcium	10 milligrams per 100 cubic centimeters
Blood phosphorus	3 5 milligrams per 100 cubic centimeters
Sedimentation rate	5 millimeters per hour
Coagulation time	4 minutes
Bleeding time	3 minutes

The blood phosphatase was elevated to 18.2 Bodansky units. A urinalysis was negative, Kolmer and Kahn tests were negative, and the tuberculin test was negative. Fifteen hundred cubic centimeters of thin serosanguineous fluid was aspirated from the thigh subfascially. Laboratory studies of the fluid

showed it to be negative on culture and smear. Microscopic examination of the sediment showed only red blood cells and blood pigment, with some round lymphoid-like cells.

On April 17, all the bones in the body were normal by roentgenogram, except the left femur (Fig. 1). At the distal third of the left femur was a lesion characterized by marked soft-tissue swelling and destruction of the bone. There had been a pathological fracture.

A provisional diagnosis of hemangioma of the lower end of the femur was made, and it was decided to examine the lesion at operation and to amputate the limb. This was done in May 1942 by A. Bruce Gill, M.D. The lower end of the thigh was incised. Bloody fluid gushed out, and then a network of white tissue was noted. This involved the subcutaneous tissue and muscles, and extended into the bony fragments, which were markedly osteoporotic. The tissue also surrounded the large blood vessels. This tissue, which resembled nerve tissue, varied in thickness and was continuous. On gross examination, no lumen was evident and no blood could be expressed from the tissue. A mid-thigh amputation was performed, and the lesion was resected as high as possible. The remaining ends of the lesion, which were at the level of the tourniquet, were ligated.

Examination of the specimen showed that the subcutaneous tissue in the region of the discolored skin was indurated and stained with blood pigment. The fascial layers and the septa were shredded, giving rise to continuous long, white strands of varying thicknesses. This condition extended from the subcutaneous tissue down to the bone, and involved the periosteum. Surrounding the large vessels, these strands were so fine and thin that they gave the appearance of spider-webbing. Between the muscles the strands were thicker, often reaching the size of small vessels or nerves. The bone was markedly porous and broke easily. It had the appearance of bone which had been decalcified by soaking it in a solution.

FIG. 3

Roentgenogram taken July 16, 1942, shows further destruction of upper end of femur and questionable involvement of the acetabulum.

FIG. 4

Roentgenogram of February 26, 1943, shows greater destruction of femur. Punched-out areas are increasing. The region of the ilium above the acetabulum also shows punched-out destructive areas.

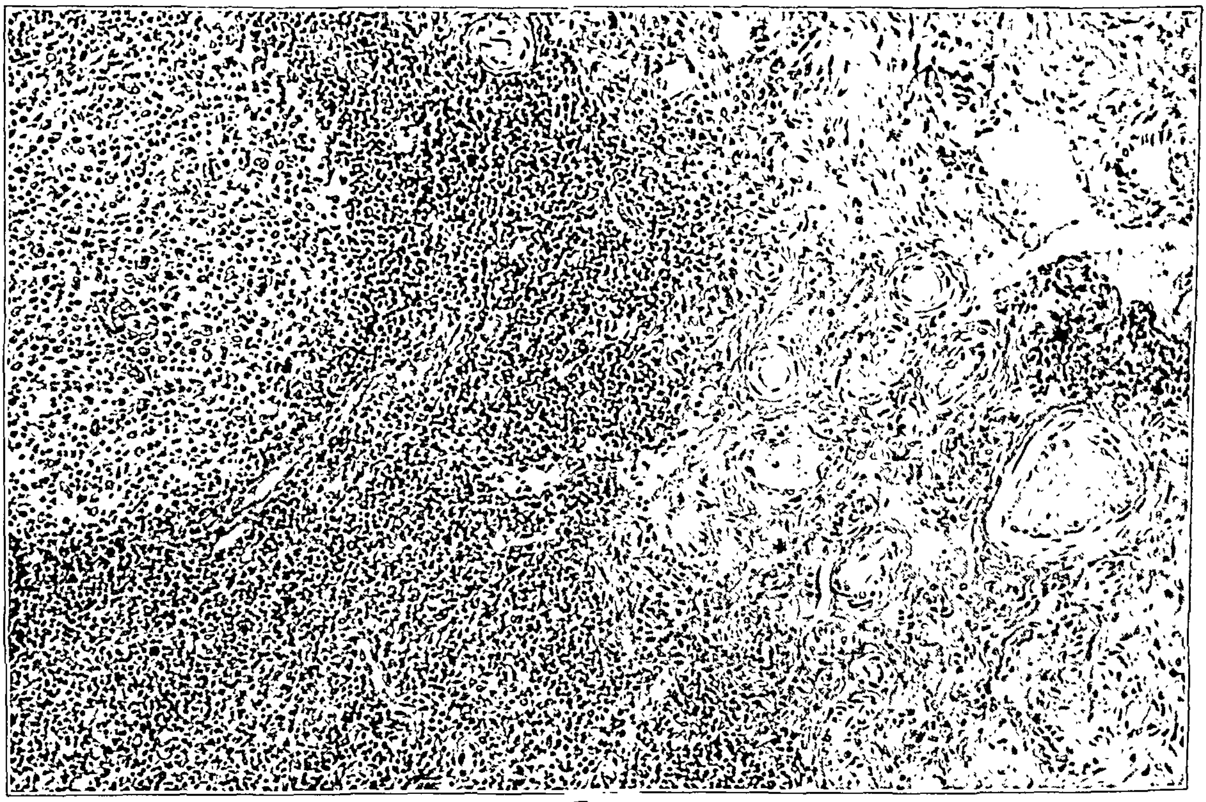

FIG. 5

Microscopic section of soft tissue shows fibrous tissue, fat, and a large number of capillary vessels. e vessels appear to be of the venous type. There is extensive fibrosis. Note the focal aggregation ymphoid cells.

The microscopic section of the femur showed considerable osteoporosis. The number of capillary blood vessels was greatly increased. This was most evident where the trabeculae were thin and widely spaced (Fig. 2). The soft-tissue sections showed fibrous tissue and thin-walled blood vessels.

The patient was discharged on June 19, 1942, with the stump healed, but boggy. His progress was followed in the Out-Patient Department. He got along well and gained weight. Roentgenograms in July showed questionable progression of the disease (Fig. 3). In November, roentgenograms showed increased decalcification and punched-out areas in the femur and acetabulum. In February 1943, he noted that the stump was becoming discolored. This was followed by swelling, and roentgenograms showed that now the head of the femur and the pelvis were involved (Fig. 4).

The patient was readmitted to the Hospital. A roentgenographic survey of the bones was again negative, except for the left hip and the stump. All laboratory studies were repeated, and found to be not remarkable, except for an elevated phosphatase (17.7 Bodansky units). On April 14, 1943, biopsy of the lesion in the left groin was performed by Paul C. Colonna, M.D. Again the plexiform mass surrounding the great vessels was encountered. A great deal of bloody-watery fluid flowed freely from the wound. The soft tissues appeared to be disintegrating, as they absorbed the fluid. Tissue was removed for examination.

Microscopically, the section showed an increased number of blood vessels, but they contained very little blood; their walls were thin, but development appeared to be normal. There was extensive fibrosis in the surrounding areolar tissue. The most striking feature, however, was the focal aggregation of lymphoid cells, sometimes grouped about well-organized germinal centers (Fig. 5).

Sections were made of eight different parts, and they were examined by Robert C. Horn, M.D., Surgical Pathologist of the Hospital of the University of Pennsylvania; Joseph McFarland, M.D., Professor Emeritus of Pathology of the University of Pennsylvania; William E. Ehrich, M.D., Pathologist of the Philadelphia General Hospital; and Arthur Purdy Stout, M.D., Associate Professor of Surgery, Columbia University, College of Physicians and Surgeons, New York City. All of these men considered the lesion to be some type of angioma.

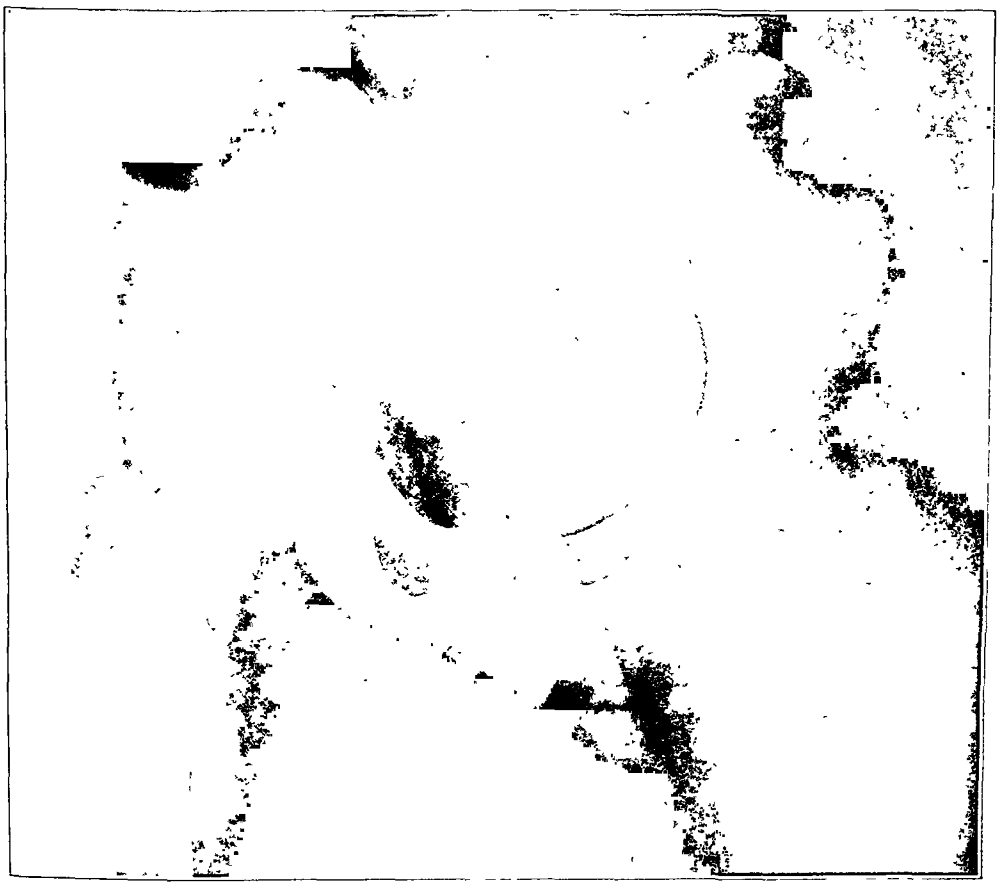

FIG. 6

Roentgenogram taken July 7, 1944, about ten months after roentgenotherapy had been stopped and twenty-six months after amputation, shows definite improvement. Calcification of punched-out areas is occurring. The disease process has definitely been arrested.

Horn reported as follows: "The sections made from the amputated leg show essentially a sprouting of capillary blood vessels, which is most evident in the bone, where the trabeculae are thin and widely spaced. Minor degrees of old and recent hemorrhage are associated with this vascular growth in the soft tissues. The sections made later at biopsy again showed increased numbers of blood vessels. The vessels here, however, tend to be of larger caliber and often have well-developed muscular walls of venous type. These vessels contain little blood. There is extensive fibrosis in the surrounding areolar tissue, but the most striking features are focal aggregates of lymphoid cells, sometimes grouped about well-organized germinal centers.

"Although the nature of this lesion is obscure, there is little doubt, on the basis of pathological examination, that neoplasm can be ruled out. (Stout agrees with me on this point.) The only suggestion I have to offer is that the changes are associated with disease (anomalous or otherwise) of the general vascular system of the leg.

"I have observed clinically and studied pathologically at the Presbyterian Hospital in New York City the case of a boy whose lesion, consisting essentially of a widespread sprouting of capillaries, presented many similarities to this case. Detailed study of that case brought to light the clinical finding of multiple small arteriovenous anastomoses; and the pathological finding of small peculiar blood vessels, which bore some similarities to arteries and some to veins. Of course, it is not known whether or not these changes were of a primary or secondary nature.[1]

"As to nomenclature, I can suggest only 'hemangiomatosis', a term without a great deal of meaning, which would, however, suggest the sprouting of blood vessels which characterizes the lesion and indicates its non-neoplastic nature."

The wound healed *per primam*. The bogginess of the stump persisted. After consultation with members of the Radiology Department, it was decided to give the patient a course of roentgenotherapy.

Between April 20 and May 27, 1943, the patient was treated with 200 kilovolts of x-ray radiation with an added filtration of 0.5 millimeter of copper, and one millimeter of aluminum with half-value layer of 1.05 millimeters of copper. The patient received 200 roentgen units to each of two portals daily, at a distance of 50 centimeters. There was an anterior portal, 15 centimeters by 15 centimeters, directed to the left ilium, the acetabulum, and the head and neck of the left femur. There was a similar posterior portal. There were also anterior and posterior portals, 10 by 13 centimeters, that covered the upper half of the femur, below the portals previously described. Each portal received 1700 roentgen units, measured in air.

The patient was followed in the Clinic, and periodic roentgenographic examinations were performed. His general condition was good. The bogginess in the stump disappeared after about six months. The roentgenograms showed progressive improvement. The punched-out areas appeared to be filling in, as was evident from films taken in July 1944 (Fig. 6). The Radiology Department feels that roentgenotherapy is no longer indicated. The fitting of a prosthesis is now being considered.

A satisfactory diagnosis for this puzzling case has not been established.

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EOSINOPHILIC GRANULOMA OF BONE

Report of a Case Involving the Clavicle

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The clinicopathological entity of "eosinophilic granuloma of bone" was described by Lichtenstein and Jaffe in 1940. Independently and almost simultaneously, the same picture was described by Otani and Ehrlich under the name of "solitary granuloma of bone". Similar cases were reported by Farber and by Green and Farber, who used the term "destructive granuloma of bone". The subject was well reviewed by Jaffe and Lichtenstein in 1944, and the basic relationship between Hand-Schüller-Christian disease, Letterer-Siwe disease, and eosinophilic granuloma of bone was stressed. To date, between thirty and forty cases of eosinophilic granuloma of bone have been reported. In this paper the authors wish to report an additional case involving the clavicle. This is a rare site for the occurrence of the condition, but one case was reported previously by Greenberg and Schein.

CLINICAL FEATURES

Eosinophilic granuloma of bone is clinically and histologically a benign inflammatory lesion. It is found almost exclusively in children, adolescents, or young adults. The lesions may be single or multiple and may involve the long bones or flat bones, or both. The clinical picture is usually that of local swelling, tenderness, redness, heat, and pain with some limitation of function, depending upon the bones involved. Systemic manifestations—such as fever, malaise, weight loss, leukocytosis, or eosinophilia—have been noted, but are rare. The lesions frequently produce no symptoms, and are discovered only by roentgenographic examination.

ROENTGENOGRAPHIC APPEARANCE

The roentgenographic picture consists essentially of an area of bone destruction. The bone may be expanded and the cortex eroded or perforated. Periosteal new bone is occasionally seen. Lesions in the skull may be sharply punched out. Sclerosis of bone about the lesion is unusual, unless pathological fracture has occurred. The roentgenographic appearance is by no means pathognomonic, and can mimic a wide variety of benign and malignant neoplasms and inflammatory lesions of bone.

PATHOLOGICAL FINDINGS

In the early stages, the gross appearance is that of soft hemorrhagic granulation tissue, which may be brown or yellowish in color and may contain areas of necrosis. The histological picture is that of a destructive granulomatous lesion, characterized by variable numbers of large mononuclear histiocytes which are actively phagocytic, interspersed among which are collections of eosinophils. The histiocytes are considered by Jaffe and Farber to be the basic component of the lesion. The eosinophils may be quite sparse, but are often present in large sheets and may present a striking red appearance in sections stained by the hematoxylin-eosin method. In some areas small numbers of lymphocytes, plasma cells, polymorphonuclear leukocytes, and multinucleated giant cells are found.

As the lesion progresses the eosinophils tend to disappear, according to Green and Farber, and the cytoplasm of the histiocytes becomes foamy, so that they take on the appearance of lipophages or "xanthoma" cells. In later stages the lesion undergoes fibrosis

and eventual transformation into bone. Jaffe and Lichtenstein are of the opinion that the disease may heal by resolution, without passing through a lipogranulomatous stage.

ETIOLOGY

The etiology of the condition is obscure. It is generally believed that the disease is of an inflammatory nature, although no specific causative micro-organism or virus has been isolated. Otani was of the opinion that trauma played a role in the pathogenesis.

TREATMENT AND PROGNOSIS

Therapy for eosinophilic granuloma has been empirical, but satisfactory. Jaffe states that the lesions may undergo spontaneous healing within from a few months to a year. Excision or curettage has been followed by complete cure with no local recurrence, although new lesions have simultaneously or subsequently appeared in other sites. Relatively small doses of roentgenotherapy have been employed, with good results.

The prognosis in general is good. In those cases with multiple bone lesions, however, there may be visceral lesions which would put the diagnosis in the category of Hand-Schüller-Christian or Letterer-Siwe disease, where the prognosis is more guarded.

CASE REPORT

An aviation cadet, twenty-two years of age, was admitted to the Army Air Forces Regional Hospital, Westover Field, on August 24, 1944, after transfer from a near-by Station Hospital. Four weeks prior to admission he first noted pain, tenderness, and enlargement of the left clavicle, approximately one inch from the sternal end. Three or four days after the onset of pain he consulted a medical officer; heat treatment and special calisthenics were given for one week. Because of persistent pain, increase in tenderness, and localized swelling, he was admitted to the Station Hospital at his base, where roentgenograms were taken. A destructive lesion was noted in the left clavicle, and a diagnosis of acute osteomyelitis of the clavicle was made. The patient was then transferred to this Hospital for definitive treatment. Upon arrival, he stated that the clavicular mass was never red or hot; it had definitely increased in size during

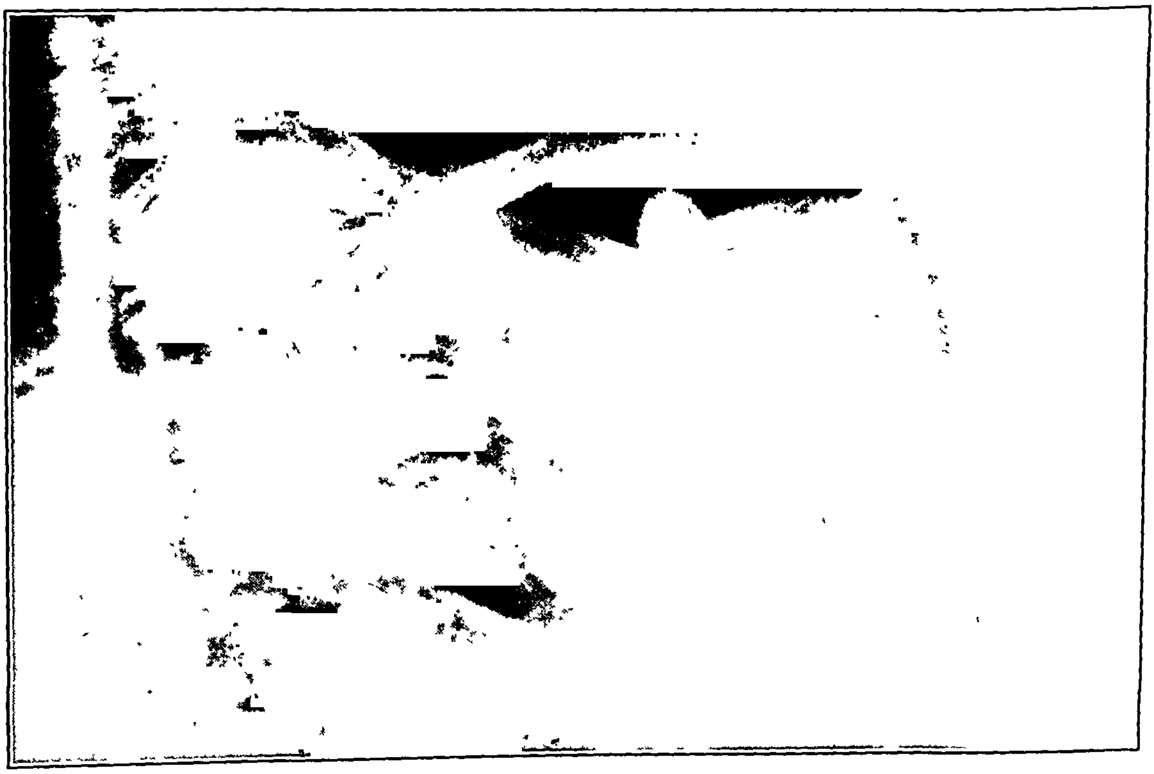

Fig. 1

Roentgenogram showing destructive lesion of the left clavicle. (*Base Photographic Laboratory, Westover Field, Massachusetts.*)

the present illness, and much more rapidly during the past one or two weeks. During the past month or six weeks he had lost from four to six pounds in weight, which he attributed to the strenuous training program of the aviation cadets. He had occasional headaches during his present illness, but no other systemic symptoms and no symptoms referable to any other portion of the skeletal system. There was no history of trauma to the affected bone. The patient's past history was not remarkable. He had been in the Army for one and one-half years at the time of admission, and had had no overseas service. His family history was relevant only in that his mother had died of what was thought to be pulmonary tuberculosis, but there was no family history of malignant or neoplastic disease.

On physical examination he was found to be a rather thin white male, seventy-one inches in height, and weighing 137 pounds. A general physical examination was negative with the exception of the left clavicle, in which there was a tender fusiform mass, one inch from the sternal end. This mass was approximately two by two centimeters in extent, was not fluctuant, did not pulsate, and did not show signs of acute inflammation. Shoulder motion and motion of the sternoclavicular joint were normal. The lymph nodes of the neck were not enlarged, but in the left axilla there was a firm, non-tender, palpable lymph node, one centimeter in diameter, which the patient stated had been tender and enlarged approximately two weeks prior to admission. There was no reaction in the skin about the clavicular mass, and no tenderness or evidence of bone involvement in the rest of the skeletal system. There were no neurological abnormalities, and the chest was clear to percussion and auscultation.

Laboratory Data

Blood Count:	Red blood cells	4,910,000
	Hemoglobin	98 per cent. (Sahli)
	White blood cells	7,900
	Polymorphonuclear neutrophils	61 per cent.
	Eosinophils	2 per cent.
	Lymphocytes	37 per cent.
Blood Chemistry:	Total serum proteins	6.4 grams per 100 cubic centimeters
	Albumin	3.9 grams per 100 cubic centimeters
	Globulin	2.5 grams per 100 cubic centimeters
	Calcium	10.7 milligrams per 100 cubic centimeters
	Inorganic phosphorus	3.1 milligrams per 100 cubic centimeters
	Phosphatase (alkaline)	3.7 Bodansky units
	Sugar	140 milligrams per 100 cubic centimeters
	Uric acid	2.9 milligrams per 100 cubic centimeters
	Cholesterol	206 milligrams per 100 cubic centimeters
	Non-protein nitrogen	37.5 milligrams per 100 cubic centimeters

The sedimentation rate was two millimeters per hour (Westergren). The Kahn test was negative. A urinalysis was negative, including a test for Bence-Jones proteins.

Roentgenographic Examination

Views of the left clavicle (Fig. 1) showed a transverse irregular elliptical area of bone absorption, measuring two centimeters by one centimeter and involving the upper two thirds of the clavicle, four centimeters from the sternal end. The edge of the defect was scalloped, hazy, and moth-eaten in appearance, with absorption through the upper cortex, leaving a residual small angular shelf, laterally and superiorly. There was no sequestration, no sclerosis or bone condensation, and no trabeculation, but slight cortical expansion was noted. An overlying soft-tissue mass, measuring approximately 2.5 centimeters by 1 centimeter, was present. Overlying the defect was a thin, opaque, elliptical rim of calcification. In comparison with roentgenograms taken twelve days previously at the Station Hospital, a definite increase in bone destruction was seen. The roentgenographic appearance was considered indicative of a neoplasm, probably malignant, rather than of osteomyelitis or other non-neoplastic condition, such as parathyroid disease. Roentgenograms of the thoracic spine, ribs, skull, lumbosacral spine, pelvis, both femora, both tibiae and fibulae, and both humeri revealed no abnormalities. A flat plate of the abdomen showed that the liver was normal, the kidneys were normal in size and position, and there was no evidence of opaque calcification. Chest roentgenograms showed the lungs to be clear, with no infiltration or consolidation.

The preoperative diagnosis was primary neoplasm of the left clavicle, probably malignant.

Operation

On August 31, 1944, a biopsy of the mass was done. The sections obtained from this biopsy showed only inflammation and necrosis, suggestive of eosinophilic granuloma, but no evidence of malignancy. In view of these findings, a thorough excision and curettage of the affected area of the left clavicle was

FIG. 2
Microscopic section, low-power field, showing sheets of eosinophils.

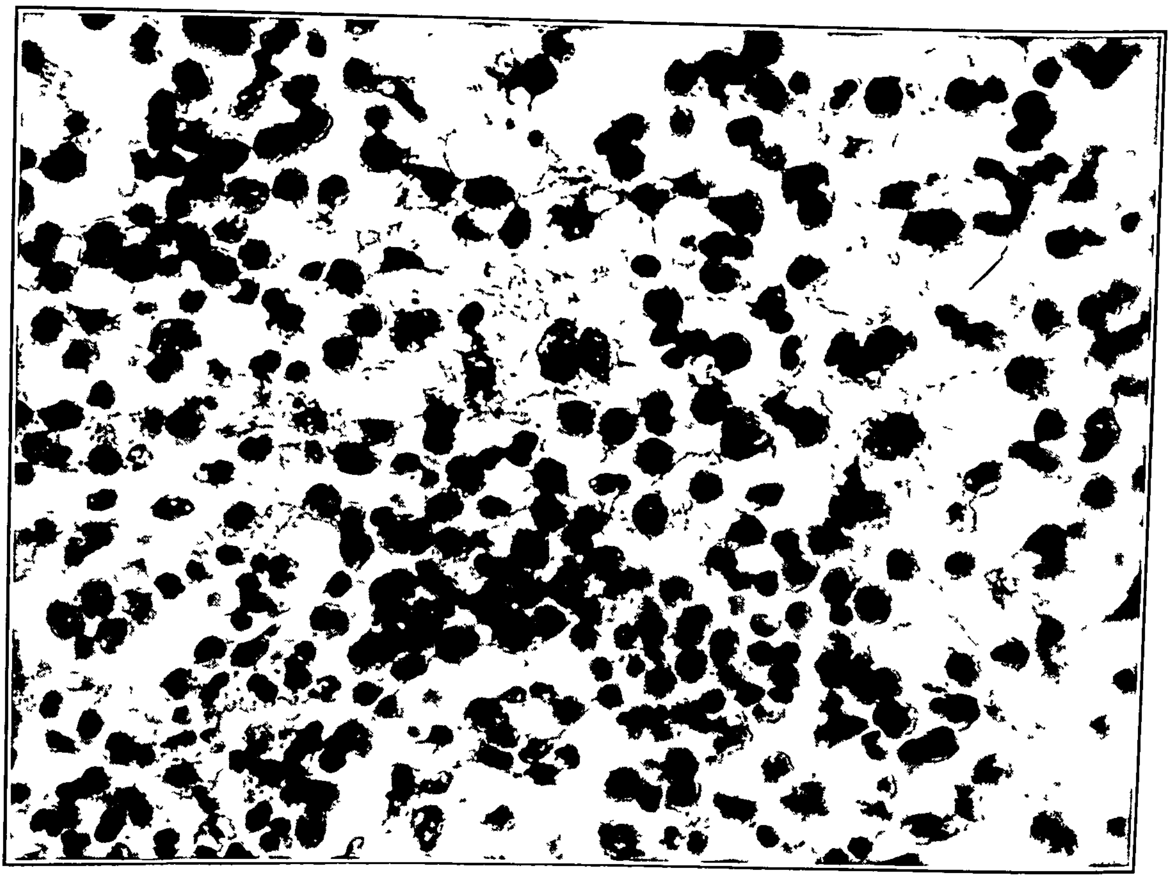

FIG 3
Microscopic section, high-power field, showing numerous eosinophils and a few large histiocytes.

done on September 2, 1944. At operation, the gross appearance of the lesion was that of a firm, reddish-gray, fleshy mass, approximately 2.5 centimeters in diameter, extending deep into the body of the clavicle. The involved tissue was friable, bled easily, and was not attached to surrounding soft tissue. There was questionable involvement of the attachment of the sternocleidomastoideus in this area, and a portion of the muscle was excised. Bleeding from surrounding bone and soft tissues was moderate. A thorough excision of the mass, curettage of the clavicular defect, and saucerization were done.

Pathological Findings

Gross Appearance: The specimen consisted of numerous fragments of friable, hemorrhagic, grayish-yellow tissue, measuring in aggregate 3 by 2.5 centimeters, and several spicules and small pieces of bone.

Microscopic Appearance (Figs. 2 and 3). Thirteen sections were fixed in a solution of 10 per cent formalin and stained with hematoxylin and eosin. The sections showed a loose vascular granulation tissue, infiltrated predominantly by eosinophils. These were mainly of the polymorphonuclear variety, although a few mononuclear forms were present. In addition to the eosinophils, there were many large cells with rounded, oval, or reniform nuclei; these were probably histiocytes, although no definite phagocytic activity could be made out. The histiocytes were occasionally multinucleated. In some sections the histiocytes were present in large sheets and were the predominating cell form. In addition to the eosinophils and the histiocytes, a small number of scattered lymphocytes and polymorphonuclear neutrophils were present. A striking feature of many of the sections was the large areas of hemorrhage, degeneration, and necrosis. In several places reparative fibrosis was noted. Small pieces of bone were present in several sections. The marrow spaces were replaced by a loose fibrous tissue, permeated by a few eosinophils and small round cells. There appeared to be a formation of poorly calcified new bone in several places. One section showed a marked proliferation of fibroblasts, with an associated formation of osteoid tissue.

Cultures taken from the site of the lesion and grown aerobically and anaerobically were sterile.

The diagnosis was eosinophilic granuloma of bone.

Progress

The patient withstood the operative procedure well, and the postoperative course was uneventful. Skin sutures were removed on the seventh day after operation, although there was still tenderness in the region of the wound, this was considerably less marked than before operation. There was no evidence of recurrence of the mass, and no drainage from the wound. Roentgenograms of the clavicle showed some filling in of the bone defect within a month after operation. The patient had normal shoulder motion, without pain. In a final roentgenogram of the clavicle, a faint elliptical translucent area was noted in the shaft of the third rib posteriorly. This finding was thought to represent another possible focus of eosinophilic granuloma of bone, and roentgenotherapy was considered to be the procedure of choice. This lesion produced no symptoms and the patient was completely free of symptoms referable to the clavicle. Since this Hospital was not authorized to give roentgenotherapy, the patient was transferred to the Walter Reed General Hospital, Washington, D. C. The roentgenographic consultant at Walter Reed General Hospital did not believe that the findings in the left posterior rib were indicative of another focus of eosinophilic granuloma, nor did he feel that roentgenotherapy was indicated so far as the clavicular lesion was concerned. Therefore the patient was discharged from the Hospital on October 31, 1944, to full military duty, to continue his work as an aviation cadet.

In a personal communication on December 26, 1944, the patient stated that he weighed 144 pounds, that his clavicle "felt fine", and that he had had no pain or recurrence of the swelling. He was carrying on full-time in the ground training program for aviation cadets, without complaint or symptoms referable to his musculoskeletal system.

COMMENT

The clinical and roentgenographic picture presented by eosinophilic granuloma of bone is not specific, and may mimic a variety of inflammatory and neoplastic processes. Thus, in the case reported, the original diagnosis was acute osteomyelitis and the preoperative diagnosis a malignant bone tumor. If the lesion is solitary, it may be confused with giant-cell tumor of bone, bone cyst, or even Ewing's tumor. Often osteomyelitis, tuberculosis, or syphilis enter into the differential diagnosis. If the lesions are multiple, they may bear a striking resemblance to multiple myeloma; the osseous lesions of lymphoma; or metastases from malignant tumors, such as neuroblastoma. The differentiation is often impossible on clinical, roentgenographic, or laboratory evidence, and will depend upon histological examination.

Eosinophilic granuloma of bone is considered by Jaffe and Lichtenstein and by Green

and Farber to be a variant of Hand-Schüller-Christian disease and Letterer-Siwe disease. Both these conditions are markedly different clinically from eosinophilic granuloma, but the histological pictures bear striking resemblances to each other and transition stages between the three diseases have been reported.

Letterer-Siwe disease occurs in young children, usually below the age of two, and in most cases runs a rapidly fatal course. It is characterized by fever, anaemia, hepatosplenomegaly, generalized lymphadenopathy, purpura, and multiple bone lesions. Histologically, there are focal or diffuse collections of histiocytes in the visceral and bone lesions, with an occasional sprinkling of eosinophils. The early lesions may be indistinguishable from eosinophilic granuloma of bone, and the older lesions may show evidence of fibrosis and the transformation of the histiocytes into lipophages.

Hand-Schüller-Christian disease occurs in older children, or occasionally in adults, and runs a milder and much more chronic course. It is characterized by the presence of lipogranulomatous foci in various viscera and bones. The classical triad of skull defects, exophthalmos, and diabetes insipidus results from involvement of the skull, although other organs and bones may be involved and the clinical picture may vary accordingly. In some cases it is possible to demonstrate the existence of focal collections of histiocytes and even eosinophils. It is believed by Jaffe and Farber that these gradually undergo fibrosis and the histiocytes are transformed into foam cells or lipophages, to produce the microscopic picture which is associated with Hand-Schüller-Christian disease.

The relationship of the three diseases is well summarized by Mallory: "Strongly suggestive evidence therefore lies at hand that all these various syndromes represent a single disease entity—rapidly fatal in the infantile forms, which have been described as Letterer-Siwe's disease and reticuloendotheliosis; chronic, but still of serious import because of the likelihood of cerebral and hypophyseal involvement, in early childhood (Hand-Schüller-Christian's disease); and comparatively benign in later childhood or in the adult, where the usual picture is that of eosinophilic granuloma. Proof of this identity must of course await the discovery of the etiology."

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DEFORMITY OF THE RADIUS PRODUCED BY AN ANEURYSM

Report of a Case

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From the Surgical Service, Orthopaedic and Vascular Sections, Ashford General Hospital, White Sulphur Springs, West Virginia

Injuries sustained during World War II have been manifested in many ways. The following case report describes a type of injury which, to our knowledge, has not previously been reported.

CASE REPORT

N. I., a soldier, twenty-one years of age, was wounded through the right forearm by machine-gun fire on February 2, 1945. He was taken prisoner, and given first-aid treatment in an enemy Aid Station. The following day he was recaptured by American troops and, after débridement of the wound, the extremity was encased in plaster. Roentgenographic examination, twenty-four hours after injury, revealed lateral displacement of the fragments of the radius (Fig. 1). On February 22 secondary closure of the wounds was performed, and the plaster cast was changed. On March 7 the cast was again changed, and traction was applied through the thumb for correction of the lateral displacement of the comminuted fragments of the radius.

Upon admission to Ashford General Hospital on April 13, 1945, the plaster cast and the thumb traction were removed. Physical examination showed a healed wound of entrance on the ulnar aspect of the lower third of the right forearm, and a healed wound of exit on the radial aspect of the upper third of the right forearm. Flexion of the right index finger was limited, with complete loss of pronation and supination of the right forearm. Palpation revealed a firm, non-tender swelling over the region of the mid-portion of the radius. Hypaesthesia was present along the distribution of the superficial radial

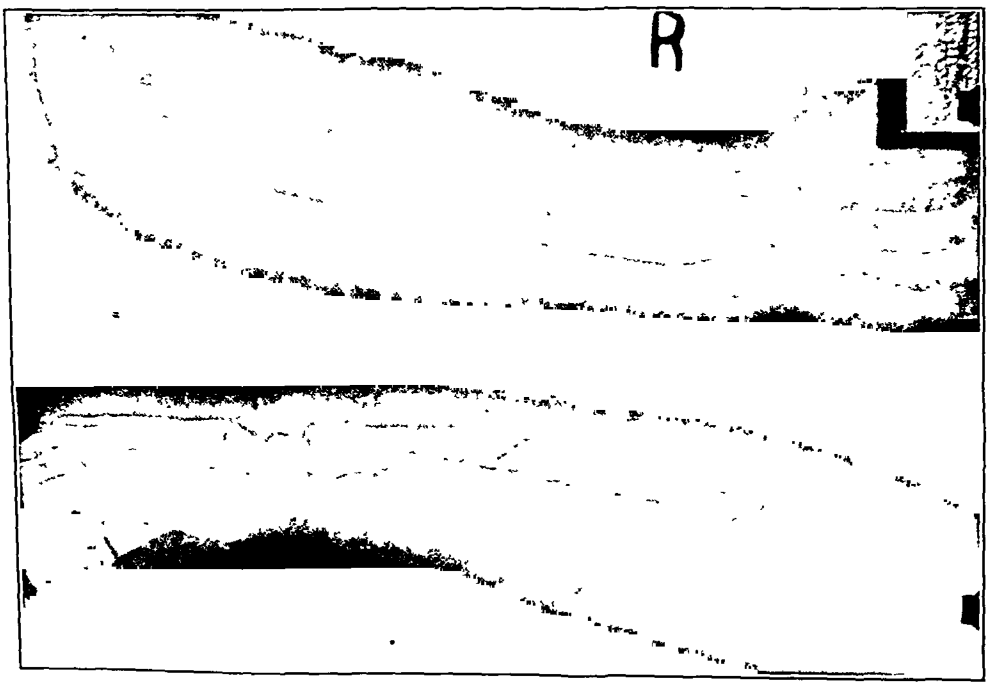

Fig. 1

Roentgenograms of the right forearm, twenty-four hours after injury. The fragments describe an even arc.

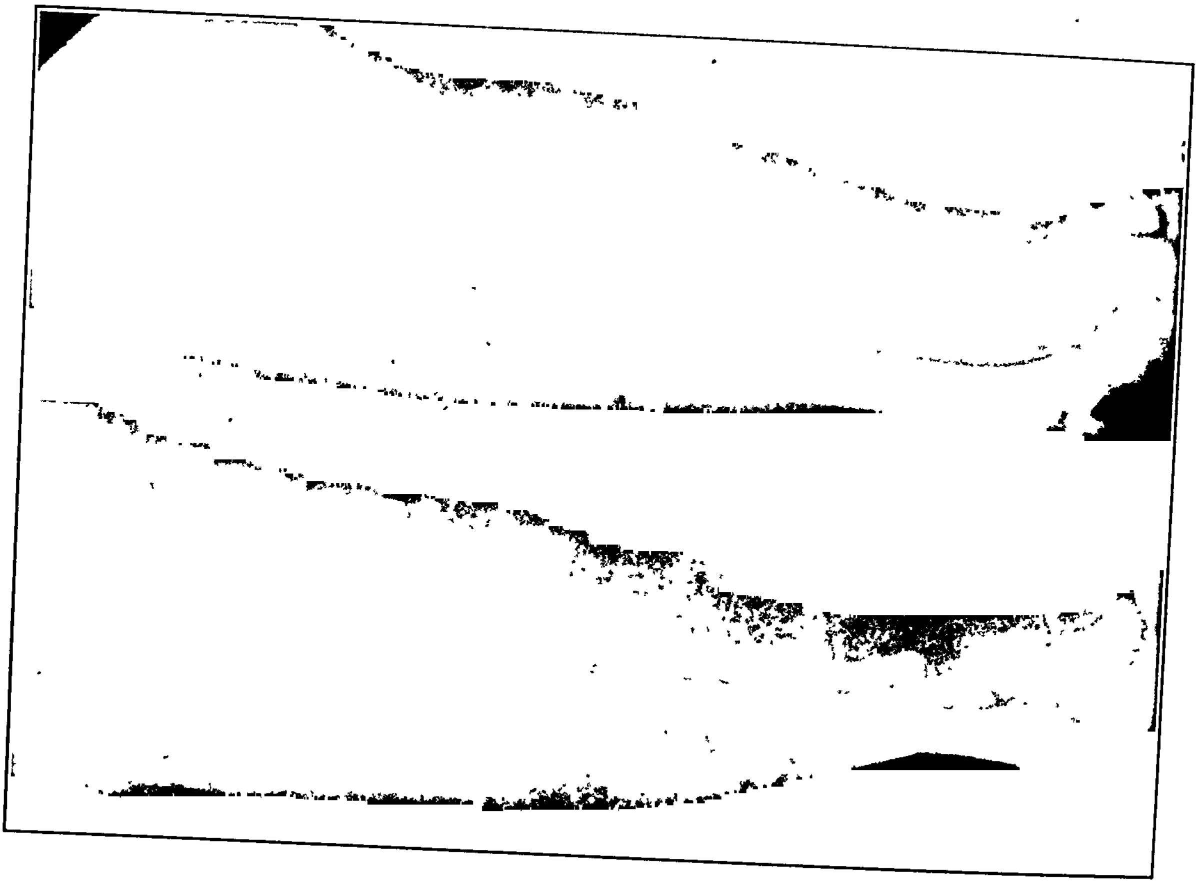

FIG. 2

Preoperative roentgenograms, taken eleven weeks after injury, show no essential change from Fig. 1.

nerve. Elbow motion was normal. Roentgenographic examination (Fig. 2) revealed the same deformity which had been noted twenty-four hours after injury. It was decided that the deformity of the radius should be excised, and the defect bridged with a tibial graft.

On May 29, 1945, with a pneumatic tourniquet in place on the arm, an incision was made between the extensor carpi radialis brevis and the extensor digitorum communis. As the periosteum was incised and stripped from the radius, a large amount of organized clot was seen. Evacuation of the clot revealed a false aneurysmal sac between the radius and ulna, measuring approximately 5 centimeters in diameter (Figs. 3-A and 3-B). The tourniquet was released temporarily, and blood spurted from a small opening in the volar surface of the interosseous artery (Figs. 4 and 5). The artery was ligated proximal and distal to the opening with No. 40 cotton suture, and the false sac was excised. The comminuted

FIG. 3-A

FIG. 3-B

Fig. 3-A: False sac of aneurysm with clot evacuated (on gauze).
Fig. 3-B: Cavity produced by false aneurysm.

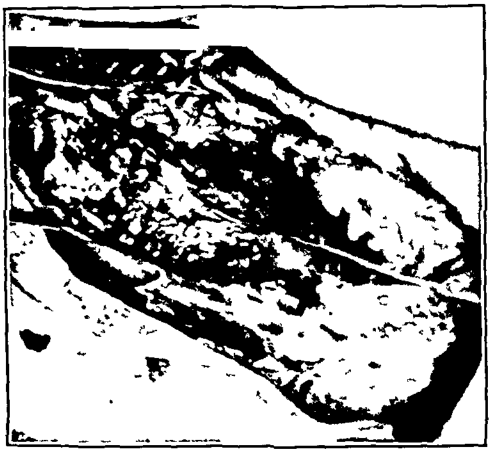

Fig. 4

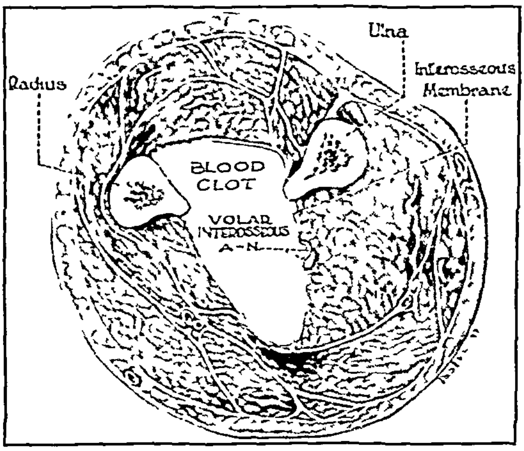

Fig 5

Fig 4: Probe inserted through opening in volar surface of the interosseous artery.

Fig. 5: Schematic cross section of the forearm at site of aneurysm, showing displacement of artery and nerve.

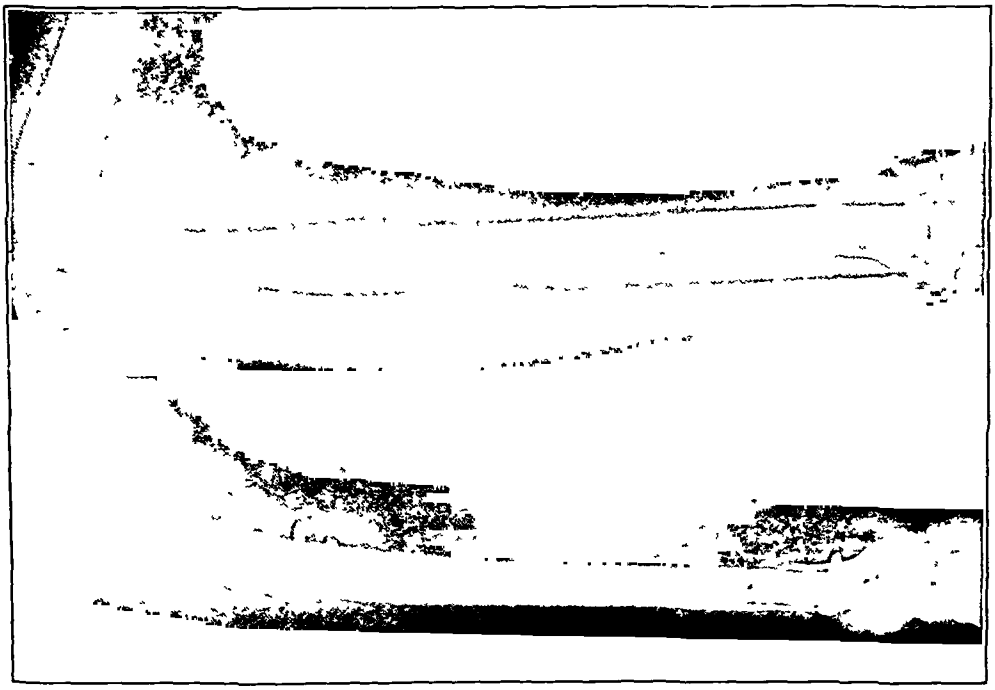

Fig 6

Roentgenograms show radial graft, four months after operation.

portion of the radius was excised, and the 11 centimeter gap was bridged by a tibial graft, measuring 13 by 1.5 centimeters The graft was fixed with two stainless-steel screws in the proximal end, and one screw in the distal end The distal end of the ulna was excised to accomplish alignment of the radial fragments, and to correct radial deviation of the hand The tourniquet was removed, and the wound was closed in layers, with interrupted cotton sutures The extremity was encased in plaster with the elbow in 90 degrees of flexion and the forearm midway between pronation and supination

The postoperative course was uneventful Four months after operation there was clinical union of the radius, with satisfactory roentgenographic appearance (Fig 6) Six months after operation supination was complete, and pronation was 60 per cent of normal.

SUMMARY AND CONCLUSIONS

The presence of this aneurysm, which produced uniform deformity of the radius, was not suspected prior to operation. From the case, the following conclusions may be drawn:

1. Uniform deformity of a comminuted bone should make one suspect the presence of an aneurysm.
2. The deformity achieves maximum size almost immediately after injury.
3. The two lesions may be corrected successfully at the same time.

CALCAREOUS TENDINITIS OF A FLEXOR TENDON OF THE FINGER

Report of a Case

BY LIEUTENANT COLONEL JOHN R. VASKO

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Amorphous calcification occurs in various tendinous tissues of the body, the usual sites being the capsule of the shoulder joint, about the insertion of the supraspinatus tendon; the capsules of the finger joints; the tendo calcaneus; and the capsule of the knee joint. The purpose of this article is to report another site of calcification, — that of a flexor tendon of a finger.

The etiology for calcification of tendinocapsular tissues is still in doubt. Some writers [1,2,3] believe that trauma is the cause, others [1] that it is a metabolic disturbance or that it is due to a deficiency of vitamin E. It has also been pointed out that necrosis of tissue, with subsequent calcification, may occur. In the case being reported here there was no history of recent trauma, although minimum injuries, such as are frequent in everyday life, may have occurred and been forgotten.

The treatment of these cases of calcification varies from no therapy to surgical removal, and includes physiotherapy, salicylates, roentgenotherapy, needling, irrigation, novocain injection, aspiration, and the administration of vitamin E. Obviously no specific therapy is effective in every case, and some of these calcifications—especially those about the shoulder—are notoriously resistant to all forms of therapy. Sutro and Cohen have observed that the calcareous deposits sometimes disappear spontaneously, without treatment. In the case to be discussed, rest alone sufficed.

CASE REPORT

E. B. H., a white male, aged twenty-eight, entered the hospital on August 12, 1944, with the complaint that his right middle finger was swollen and pai[illegible] on the volar surface. The onset was gradual.

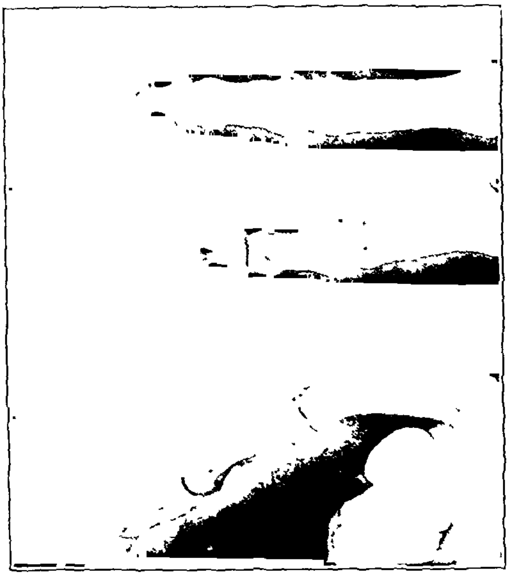

FIG. 1

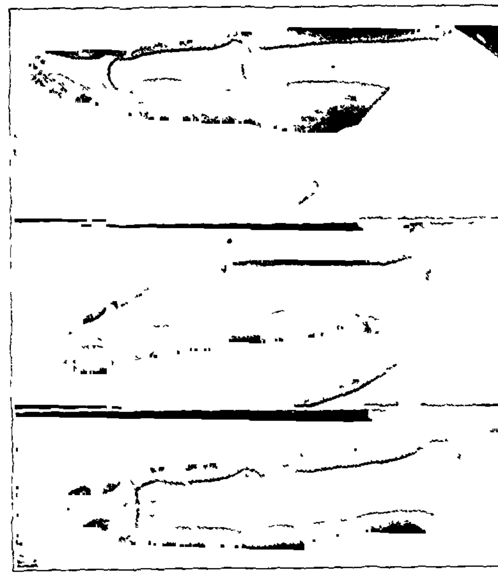

FIG. 2

Fig. 1: Shows calcification within the flexor tendon on August 14, 1944, before treatment was begun.
Fig. 2: Shows the calcification two weeks later, after treatment was begun.

and had begun three or four weeks before. The patient remembered no recent injury to the finger, and, since he was an office worker, minor injuries due to his occupation were unlikely. He stated that in 1935 he had injured the finger while playing football, but had had no trouble with it until recently. No other joints were affected. The past history was unremarkable. The patient's chief complaints were pain, swelling, and limitation of motion of the distal interphalangeal joint of the right middle finger.

The physical examination was negative, except for some caries of the teeth and for the right middle finger. This finger was moderately swollen about the middle phalanx on the volar aspect; it was tender, and there was limitation of motion of the distal interphalangeal joint. There was no redness, adenopathy, or fever.

The roentgenographic report was as follows: "X-ray of the right hand reveals that there is a saucer-shaped area of ossification, measuring 15 millimeters in length, 7 millimeters in breadth, and 5 millimeters in thickness, lying in the soft tissues anterior and proximal to the distal interphalangeal joint. There is also a spur from the anterior margin of the joint surface of the distal phalanx. These changes are probably posttraumatic, and probably related to such pathological changes as a tendinitis or myositis ossificans."

The blood findings were as follows:

Red blood cells	4,440,000
Hemoglobin	90 per cent.
White blood cells	5,950
Polymorphonuclear neutrophils	60 per cent.
Lymphocytes	35 per cent.
Eosinophils	5 per cent.

The urine was yellow and hazy, and gave an acid reaction; the specific gravity was 1.026; tests for albumin and sugar were negative.

The tentative diagnosis was calcification of the deep flexor tendon, the tendon sheath, or both.

Progress Notes

On August 14 the diagnosis was still uncertain, but there appeared to be calcification of the tendon at its distal end, near its insertion near the spur on the volar surface of the base of the distal phalanx (Fig. 1). On August 16 surgical intervention was planned, and an aluminum finger splint was applied to the flexed finger. By August 21 the swelling and inflammation had subsided considerably. A furuncle had developed on the wrist, and surgery to the finger was postponed. The carbuncle was opened on August 22, and a dressing was applied. Dry heat, three times a day, was advised. By August 29 the carbuncle had practically healed, and no drainage was present. The finger was no longer swollen or

FIG. 3
Four months later, hardly any trace of the calcium remains.

painful. Roentgenograms showed a disappearance of the calcification (Fig. 2). The patient was to be discharged to duty. He was to return to the hospital, if necessary, and to be followed in the clinic.

The patient was seen again on January 11, 1945. At that time he had no swelling, pain, or tenderness of the finger, and the function was normal. A small spur could be felt on the flexor surface of the distal phalanx. Roentgenograms (Fig. 3) showed only the faintest trace of the previous calcification. The patient was performing full duty, and had received no treatment to the finger since leaving the hospital, other than continuation of the splint for an additional two weeks.

COMMENT

This patient's injury to his finger while playing football, nine years before, probably caused the spur on the distal phalanx. It is unlikely that this original injury was a factor in producing the calcification, because the patient was free from symptoms until shortly before admission to the hospital. The spur, however, may have been a contributing factor by causing local irritation during joint movement. The rapid disappearance of the calcium deposit, with rest alone, would tend to substantiate the latter hypothesis. Calcareous deposits, however, frequently disappear spontaneously without treatment, which invites speculation. Possibly in these cases a reversible local or general metabolic process is present, which, upon returning to normal, causes the absorption of the deposit. What effect the splint produced in this case, therefore, is uncertain. Until our knowledge of the etiology of these deposits is greater, the rationale of treatment cannot be entirely sound, which suggests that conservative treatment should always be tried first.

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THREE INSTRUMENTS DESIGNED TO FACILITATE THE BANKART OPERATION FOR RECURRENT DISLOCATION OF THE SHOULDER *

BY CAPTAIN R. G. LAMBERT AND COLONEL THOMAS HORWITZ

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The operation described by Bankart in 1938 for repair of recurrent dislocation of the shoulder is admittedly the only anatomical and physiological operation which has been described for this condition. All other operations provide substitutions and fail to correct the true cause of the disability, in spite of the fact that a high degree of success has been obtained with some of them. Bost and Inman, reporting ten cases of Bankart repair in 1942, fully corroborated Bankart's original contention that the basic pathological process is a tearing away of the glenoidal labrum from the anterior aspect of the glenoid fossa, with or without tearing of the anterior capsule.

In spite of the fact that the aim of the Bankart operation is a simple one—that is, drilling two or three holes in the glenoid lip, passing sutures through the holes, and fixing the glenoidal labrum back in place by tying the sutures over the detached labrum—the procedure is actually fraught with numerous technical difficulties, which probably account for the failures (in a small percentage of

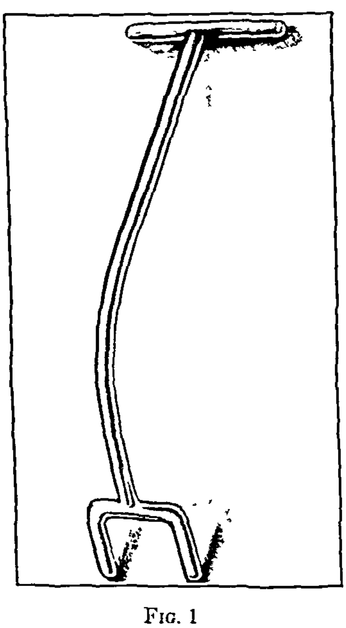

Fig. 1

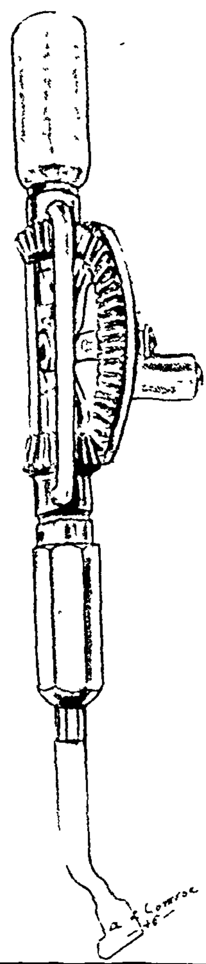

Fig 2-A

Fig. 2-B

Fig. 1: Curved Y-shaped "pusher" type of retractor for displacing the head of the humerus out of the operative field.

Fig. 2-A: The right-angle drill, constructed by modifying a hand drill to fit the hand piece of a standard dental drill; used for drilling the holes through the lip of the glenoid fossa.

Fig. 2-B: The hand piece of the dental drill, with drill attached.

* Presented at the meeting of the Chicago Orthopaedic Society, Vaughan General Hospital, Hines, Illinois, April 13, 1945.

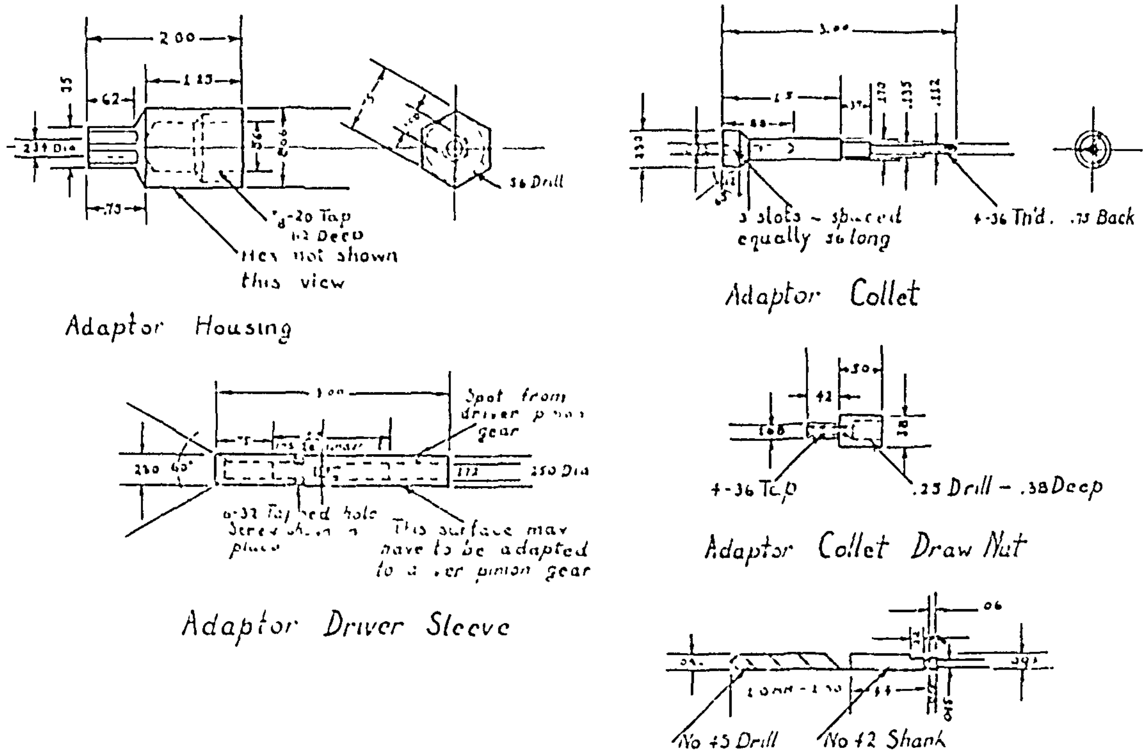

FIG. 3-A

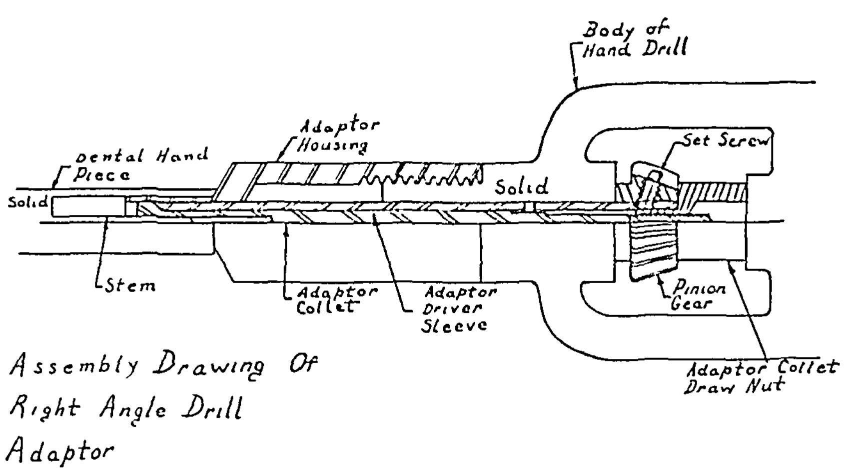

FIG. 3-B

Adaptor Housing: Fits on the end of the drill and serves as an adaptor between the drill and the dental hand piece, which is locked in position by the hexagon at the end of the housing.
Adaptor Driver Sleeve: Fits into the adaptor housing and transmits the actual power from the driver pinion to the adaptor collet; also serves to tighten the collet on sleeve lock in conjunction with the adaptor collet draw nut.
Adaptor Collet: Transmits power to the stem of the dental hand piece.
Adaptor Draw Nut: Acts in conjunction with the adaptor driver sleeve to tighten the adaptor collet on the stem of the dental hand piece.
The Drill: Modification of a standard drill, No. 45, to fit the dental hand piece.

cases) following this procedure. The operation has proved most difficult and trying to surgeons who have attempted its use, and for this reason other methods, such as the Nicola or Henderson operations, have been preferred.

In performing the Bankart operation, three obstacles are at once apparent: The head of the humerus is directly in the operative field, and can be kept out of the way only by the determined efforts of one or more assistants. A straight drill can be introduced into the field only with great difficulty; and, after the holes have been drilled, there is no suitable instrument which will carry the sutures easily through the holes.

Taking these problems in order, three pieces of equipment have been constructed. To facilitate constant displacement of the head of the humerus, a Y-shaped instrument was devised (Fig. 1), which is placed with the Y portion about the neck of the humerus, just

below the capsule. An assistant on the opposite side of the operating table, by pressure on the handle, easily displaces the head of the humerus posteriorly and laterally, giving exposure of the entire glenoid fossa.

The most difficult problem—that of constructing the drill holes—was solved by developing a right-angle drill. A few modifications were made in an ordinary mechanic's drill, and a standard dental drill tip was attached (Fig. 2-B). The result is an instrument which expedites the construction of the drill holes in the glenoid lip. Even though this drill tip is small enough to be inserted between the head of the humerus and the glenoid, it has been found easier to work from the medial side of the scapula and to drill toward the joint. Drill points are fastened into the dental tip by a snap lock, and, by being made flat on one side, they mesh with the driving mechanism. These drill points may easily be constructed from a standard drill, size No. 45 (Fig. 3-A).

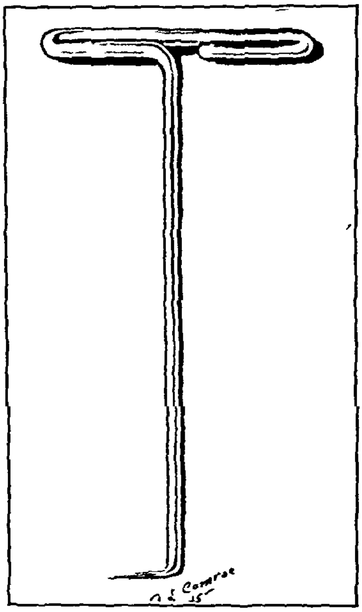

FIG 4

The right-angle suture carrier, made of a size to fit the drill holes, with a small hook on the end to catch and deliver the suture through the holes.

The difficulty of passing the sutures through the holes was met by devising a right-angle suture carrier of a size to fit the drill holes. The tip of the carrier has a small hook, which catches the heavy braided silk suture and delivers it through the drill hole (Fig. 4).

These three pieces of equipment are simple enough of design to be made by any qualified mechanic or brace maker; and, including the dental drill tip, they cost less than $15.00.

In eight patients operated upon by the authors, the equipment just described has been used; and it has proved invaluable in facilitating a most difficult and tedious operation. On first using these tools in two cases, the authors have reduced the operating time to one hour and forty minutes and one hour and thirty minutes, respectively, from skin incision to dressing. It should not be assumed from this that the operation has been made simple in all cases Each author has encountered a case in which, for some unknown reason, the head of the humerus could not be displaced out of the field, and the operation was consequently difficult. It is felt, however, that, without the tools described, the Bankart operation could not have been carried out in these two cases.

The pathological findings in each case have sustained Bankart's contention as to the basic lesion in recurrent dislocation of the shoulder. Since the eight patients have all been operated upon within the past five months, no end results are presented, although there have been no recurrences to date It is not the purpose of the authors to discuss the relative merits of the Bankart operation; but they feel that the correction of the fundamental pathological process in any lesion, when possible, offers the most certain promise for physiological recovery

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RUPTURE OF THE PECTORALIS MAJOR

Report of a Case

BY DANIEL M. KINGSLEY, M.D., NEW ORLEANS, LOUISIANA

Reports of rupture of the pectoralis major are rare. Pulaski and Chandlee summarized the literature on seventeen patients with this lesion, and included one case of their own. A nineteenth patient was described by Parkes. The present paper adds the report of another case.

It would seem, however, that the condition is not so rare as the literature might lead one to conclude. Pulaski and Chandlee mention the statement of Saar, Bernhard, and others that "the injury is not uncommon in sports but is infrequently diagnosed". Bunnell mentions these ruptures, and describes their repair. The paucity of reported cases probably is due to the fact that any one surgeon usually encounters only a solitary instance and does not consider it worth reporting.

Rupture of any of the larger muscles is seen infrequently. For example, review of all available record files at Charity Hospital of Louisiana in New Orleans, with admissions in some years ranging as high as 69,229, fails to reveal a single instance of rupture of the pectoralis major. Indeed, the diagnosis of rupture of any muscle was infrequent. In a year's work as orthopaedic surgeon for an infantry camp which had a total population (including turnover) of about 65,000 men, engaged in training of a violent and urgent character, the author encountered only three tears of large muscles or tendons, as follows: one each of the supraspinatus, the quadriceps femoris, and the tendo calcaneus. It should be noted that all of these injuries occurred in extremities.

Pulaski and Chandlee summarized the etioloy of the recorded tears of the pectoralis major, as follows:

Group 1.	Due to senile changes	2
Group 2.	Due to direct violence	1
Group 3.	Due to strong pull on the contracted muscle	10
Group 4.	Combination of direct blows and violent pull	5

Parkes's case comes under Group 3.

The following case history falls into the category of rupture due to a strong pull on a normal, contracted muscle.

CASE REPORT

History

A white male, aged twenty-six, with powerfully developed muscles, had been a nationally known football player in college. After graduation, he was employed as an engineer. In the course of his work, he entered a deep hole, bordered by a concrete wall. On attempting to climb out, he grasped the edge of the wall some distance above his head. His right forearm was on top of the wall, and his fingers had a good grasp of the far edge. Most of his weight (195 pounds) was suspended from his right upper extremity. His left arm was helping to lift him by pushing from below. Because of the small diameter of the hole, he could not use both arms to equal advantage. Therefore, not much force was being exerted by the left upper extremity.

As he tensed the muscles of his right upper extremity in attempting to lift himself, the patient felt a sudden, severe, tearing and burning pain in the area of the right chest, anteriorly. The upper extremity on this side immediately became totally disabled, but he managed to get out of the hole.

Pain prevented the patient from using the right arm for about two weeks. There was no other area of pain, and the shoulder joint was normal. Any motion which stretched the right pectoralis major could not be performed, because of pain. Hemorrhage was noticed immediately after the injury. It began in the area of the right anterior axillary wall, but soon extended down the anterior chest wall to the region of the upper abdomen. It resulted in marked subcutaneous color changes, which persisted for a period of three weeks.

Because of the inability to use his arm, the patient consulted a surgeon, who correctly diagnosed the condition and advised suture of the muscle. The patient refused operation, however, and the only treatment consisted of application of a Velpeau type of bandage. Gradually, over a period of a month, strength returned in large measure; but the patient has been aware of the fact that, since his injury, his right arm has not been quite so strong as it had been previously. He stated, however, that he has always considered his residual disability as inconsequential.

Physical Examination

Eight years after the original injury, examination was performed for a minor condition not related to the muscle. The muscle injury was discovered during the course of the general examination. The patient had large bones and powerful muscles, but had not kept up his former athletic training. In the course of appropriate functional tests, the only abnormality which could be found was that muscle strength of the right pectoralis major was slightly, but definitely, decreased by comparison with the corresponding muscle of the intact left side. There was moderate flattening of the right pectoral area, most conspicuous at the deltopectoral junction. The flattening was not marked when the arms were at the sides, but was easily apparent when the arms were held in partial abduction, especially when resistance was exerted. The anterior axillary fold was more nearly vertical on the injured side than on the normal left side, so that the axilla itself was more shallow on the right.

On palpation, the right anterior axillary fold was decreased in thickness about 50 per cent. more than that on the left side. In the anterior axillary wall, the entire thickness of the sternocostal portion of the pectoralis major was absent in a longitudinal area corresponding to the junction of the muscular and tendinous portions. Here a thin scar, about three centimeters long, connected the mid-portion of the tendon to the atrophied sternocostal portion of the muscle which remained. The sternocostal portion of the muscle was functioning, but it was decreased about 75 per cent. in mass. The clavicular portion showed only a trace of decrease in mass, and the abdominal portion was slightly decreased. Across the area of the tear in the muscle was a skin crease, where the skin had become slightly adherent to the scar underneath.

The slight degree of functional impairment in this case seems to be due to two factors: first, the transmission of muscle power through the scar to the tendon; and second, the minor role of the sternocostal portion of the muscle in the ordinary use of the arm, as has been shown by Inman, Saunders, and Abbott.

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CONCEALED CYSTS OF THE LATERAL MENISCUS OF THE KNEE

Report of a Case

BY R. J. DITTRICH, M.D., DULUTH, MINNESOTA

Cysts of the menisci are not uncommon, although only in recent years have they received much attention. They are found most frequently in the lateral meniscus. The diagnosis is, as a rule, not difficult, as the cysts occur almost invariably at the outer margin of the meniscus, and thus are palpable or visible at the time of examination.

Ollerenshaw reported in 1935 that he had treated forty-two cases, of which thirty-six occurred in the lateral meniscus and six in the medial meniscus. Among these was "one case in which the cyst arose from the free border of the external cartilage and projected towards the middle of the joint, lying against the crucial ligaments". This was found in a girl, eleven years old, who gave a history of a sprain of the knee at six years of age, and subsequently had occasional attacks of stiffness and locking. The operative approach was made through a mid-line incision, splitting the patella. "On retraction a cystic swelling, the size of a cherry, was found to be attached to the free (medial) edge of the outer semilunar cartilage and lying closely against the crucial ligaments. The cartilage was an unusually broad one. It was excised completely with the cyst."

In a survey of 110 publications on this subject, Sjövall reviewed 358 cases, including twelve of his own. He discussed at great length the etiological, pathological, and therapeutic aspects of this condition. In this material he was able to find only one case of concealed cyst,—that reported by Ollerenshaw.

CASE REPORT

The patient seen by the author was a male, aged thirty-two, who was employed as a shipfitter's helper. He was seen about two hours after he had slipped on the deck of a ship, twisting his left knee. This accident was followed by intense pain and mild swelling; and the knee was held in a position of slight flexion, from which it could not be completely straightened.

The man stated that four years before, while working on a farm, he had had a similar, although less severe, injury to the same knee. At that time he had moderate pain, with no restriction of motion. He had recovered in about one week, and since then he had occasionally had slight pain. He stated that he had been rejected for military service, owing to this knee condition.

Examination showed that the patient had a moderate limp on the left, and in walking the knee was flexed to about 30 degrees. Active motion in the left knee was present from 90 to 150 degrees; passive extension was obtained up to 170 degrees. On active and passive motion, pain was produced on the anterolateral aspect of the knee joint. No effusion was noted, but a mild puffiness spread anterolaterally over the joint space, and in this area there also was definite tenderness. No abnormal anteroposterior or anterolateral mobility was noted, and no pain was produced on attempts to rotate the leg. There was no point of tenderness elsewhere about the knee joint.

Roentgenographic examination, including anteroposterior and lateral views of the left knee, showed no abnormality.

The man was seen two days later, at which time his knee had become somewhat more painful. There was little or no change in the objective findings from those noted previously. A diagnosis was made of rupture of the left lateral meniscus, and it was considered advisable to undertake an exploratory operation of the joint.

Operation, four days after the injury, consisted of an incision lateral to the patella, with a longitudinal incision through the joint capsule. About 10 or 15 cubic centimeters of viscous, straw-colored fluid escaped from the joint. After the joint capsule had been opened, the anterior portion of the lateral meniscus was found to be detached and hypermobile; near the anterior pole of the lateral meniscus a small swelling was found, which had the appearance of a cyst. This was about one centimeter in diameter, and arose from the superior surface of the anterior portion of the meniscus. A similar cyst, about five by two by two millimeters in size, was found to arise from this area and to be separated from the larger swelling by about two or three millimeters. The meniscus was freed from its attachments and removed as far posteriorly as possible; the posterior portion was left intact. The incision was closed in layers.

The postoperative course was favorable, with the exception of a small hematoma, which developed in the subcutaneous tissue; this was evacuated several days after the operation.

The man returned to his former work seven weeks after the operation. He was seen again about three months after the operation, at which time he stated that he had been working regularly. He had no complaints of pain or other disability. Motion in the knee was present from 75 to 180 degrees; there was no tenderness or effusion, and power of the knee in extension and flexion was estimated at 80 per cent. of normal.

The pathologist's report, limited to a description of the larger cyst, is as follows: "Macroscopically, the specimen consists of a cyst one centimeter in diameter, with rather thick walls (two millimeters) and smooth inner surface. The cyst is attached, over an area of about one centimeter in diameter, to a base of fibrocartilage. Microscopically, the cyst has thick, fibrous walls with few cells. The nuclei are small and the interstitial tissue is extensively hyalinized. The cyst is lined with a synovial-like membrane, with flattened cells. There is no inflammatory or neoplastic type of proliferation or infiltration."

COMMENT

This case is of interest for the reason that cysts arising from this location are evidently very rare. There is no certain way of determining the time of origin of the tumors in this case, and it is questionable whether they were the cause of any part of the patient's complaints. It seemed at the time of the operation that the detachment of the meniscus was probably the cause of the man's disability. From the location of the cysts near the anterior pole of the meniscus, it is probable that during motion there was no serious disturbance, as the tumors probably receded into the intercondylar space, and in this manner escaped compression by the lateral condyle in full extension.

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FOOT EXERCISER

BY CHARLES F. SCHROEDER, M.D., EVANSTON, ILLINOIS

The foot exerciser described herein was designed to meet the need for some device for the bedridden patient which would provide easily regulated resistance to both dorsal and plantar flexion of the foot. The exerciser fills these requirements in that it permits adequate control over the amount of resistance to flexion, the range of foot motion, and the duration of active motion. It was intended primarily for the patient with a leg fracture, but it may be used for any condition where active resistive foot motion is indicated.

Figures 1 and 2 illustrate the way in which resistance to dorsal and plantar flexion is created. The exerciser is shown, viewed from the side, mounted on a Thomas leg splint. The exerciser is placed on the frame of the Thomas splint, with the base piece of the exerciser above the frame and the flat metal bar of the clamp attachment below.

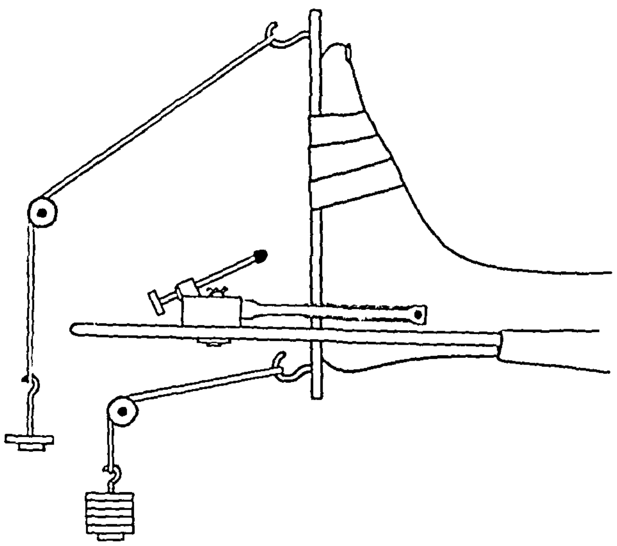


FIG. 1

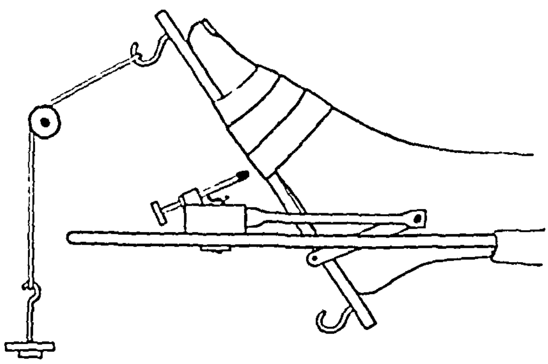


FIG. 2

Fig. 1: *Resistance to Plantar Flexion:* In order to obtain plantar flexion of the foot, the patient must overcome the pull of the lower set of weights.

Fig. 2: *Resistance to Dorsal Flexion:* The lower rope has been removed from the bottom hook of the foot piece. In order to obtain dorsiflexion of the foot, the patient must overcome the pull of the remaining set of weights.

The exerciser is then moved on the frame until the patient's foot and the foot piece are closely approximated. There it is immobilized by tightening the two wing nuts of the clamp attachment. The patient's foot is then secured to the foot piece with an elastic-type bandage. (Movement of the foot is prevented by adjusting the stop to hold the foot piece in the upright position.) When active motion is desired, the stop (shown in Figure 3) is first unscrewed until only a few degrees of flexion are possible. The threaded rod of the stop can be set at any desired position, and therefore the range of foot flexion can be rigidly controlled. The active motion may be free if no weights are attached to the foot piece.

When active resistive motion is desired, the two ropes, which support weights, are attached to their respective hooks, as illustrated in Figure 1. The individual needs of each patient may easily be met by regulating the range of foot motion, adjusting the amount of weight used for resistance, and prescribing the duration of active motion. In the case of a fracture, the three factors are increased within the limits of pain, muscle spasm, and safety to the healing bone. When the patient can tolerate unlimited activity, the stop is unscrewed until it no longer interferes with foot flexion. In the early stages of the fracture, it is advisable not to exercise the foot against resistance to plantar flexion. The counter-

pressure against the base of the foot, transmitted axially, may tend to disrupt the continuity of the fracture.

The possibility of development of foot drop is very unlikely, because the patient exercises his foot against resistance to dorsal flexion; and whenever the patient relaxes his foot, it is automatically pushed into the upright position. This is done automatically because the weight pull for resistance to plantar flexion is sufficient, against the counterpull of the other set of weights, to maintain the foot upright. The foot may be kept upright by setting the stop.

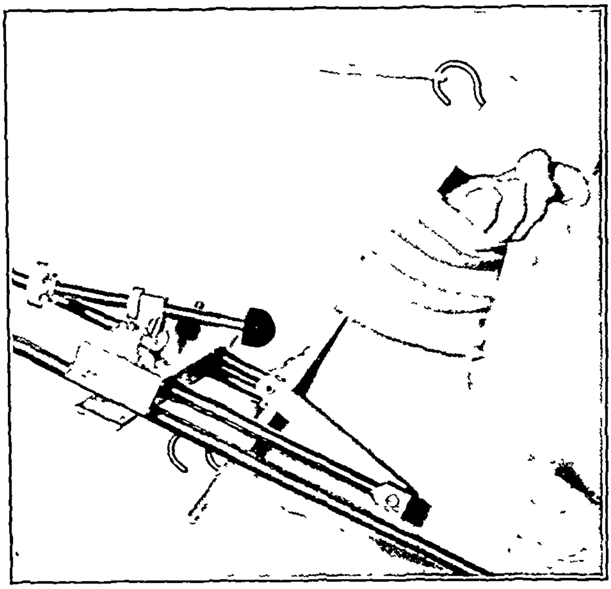


Fig. 3

The stop can be seen on top of the base piece. The wing nuts of the clamp attachment are on either side of the threaded rod of the stop. The main hinge of the foot piece coincides with the axis of the ankle joint.

The exerciser may be used on plaster-of-Paris casts. The part of the cast covering the patient's foot, ankle, and tendo calcaneus may be removed. A Pearson attachment or small Thomas splint is then incorporated, with plaster bandages on the cast. The frame of the splint should be parallel to the leg and one-half inch below the center of the ankle. The exerciser is then mounted and used on the frame, as has been previously described. The Pearson attachment can be incorporated in the cast when it is first applied, if foot, ankle, and tendo calcaneus are not covered. The motion of the foot, including lateral motion, is well restricted by immobilizing the foot piece with the stop, and securely bandaging the patient's foot to the foot piece.

The exerciser is also capable of producing powerful dorsal flexion of the foot, and can therefore be used in the conservative treatment of a shortened tendo calcaneus. The patient's leg is first immobilized by placing it in a cast or in a Thomas splint. If a Thomas splint is used, it is necessary to use countertraction to the skin to maintain the close approximation of the patient's foot to the foot piece. In order to create dorsal flexion, the upper rope pulls in the opposite direction from the lower one; and the pull of both weights combines to produce a powerful, easily regulated dorsal flexion.

SAMUEL FOSDICK JONES

1874–1946

S. Fosdick Jones, known to his host of friends affectionately as "Dick", died March 24, 1946, in Los Angeles. Born in Cincinnati, Ohio, August 4, 1874, he attended Hill School at Pottstown, Pennsylvania, Massachusetts Institute of Technology, and, finally, the College of Physicians and Surgeons (Columbia), New York, where he was graduated in 1902. His professional career started in New York as an intern at the Presbyterian Hospital, The New York Foundling Home, and the Hospital for Ruptured and Crippled. In the latter institution, while working under Dr. Virgil P. Gibney, he became interested in orthopaedic surgery. This association developed into a lifelong and unusually close friendship, and Dr. Gibney's picture always had a prominent place among the many photographs in Dr. Jones's library.

Because of his health, he was sent to California; after a rest of about a year in Pasadena, he went to Denver, where he started in practice in 1906. This city always had a warm spot in his heart for, as he said: "It gave me my health, my practice, and my wife". In 1910 he was married to Mary Catherine Cordes.

For twenty-four years in Denver, he was active in the practice and teaching of his specialty; he was Professor of Orthopaedic Surgery at the University of Colorado School of Medicine, and at the time of his death was Professor Emeritus. In 1930 he had to retire on account of poor health. His last years were spent in Pasadena, California.

In addition to membership in The American Orthopaedic Association, of which he was at one time Vice-President, Dr. Jones belonged to the Western Surgical Association, Clinical and Pathological Society of New York, The American Academy of Orthopaedic Surgeons, American Medical Association, and American College of Surgeons.

He was, above all, a gentleman in every sense of the word. In spite of poor health, he continued his work with courage as long as was possible. He was characterized by his determination to succeed in spite of his many handicaps, and by the great bravery with which he met each succeeding illness. "Life was a wonderful adventure to him."

DAVID SILVER

1873–1946

David Silver was born in Wellsville, Ohio, March 16, 1873, the son of David Silver and Nancy Elizabeth Hammond Silver. He was graduated from Exeter Academy and Harvard University. After he had received his degree of Doctor of Medicine from Harvard Medical School in 1899, he did postgraduate work in Germany and Austria until 1901. Soon after his return to this country he entered upon his practice in Pittsburgh. He actually established orthopaedic surgery in Pittsburgh, and achieved outstanding success in this field.

Dr. Silver was Professor of Orthopaedic Surgery at the University of Pittsburgh for many years, and later was Professor Emeritus. He was head of the orthopaedic department of the Allegheny General Hospital, Pittsburgh, for thirty years. From the time of its establishment in 1919 until 1944, he was in charge of the D. T. Watson Home for Crippled Children, at Leetsdale, Pennsylvania. He was consulting orthopaedic surgeon at Children's Hospital, Pittsburgh Hospital, and the Industrial Home for Crippled Children. He was Orthopaedic Consultant for the United States Army during World War I, in the Surgeon General's office.

He contributed to the literature many publications dealing with orthopaedic problems. His medical affiliations included the American Medical Association, the Medical Society of the State of Pennsylvania, the Pittsburgh Academy of Medicine, The American Board of Orthopaedic Surgery, The American

DAVID SILVER

Academy of Orthopaedic Surgeons, and the Clinical Orthopaedic Society. He was a Founder and Fellow of the American College of Surgeons. He became a member of The American Orthopaedic Association in 1906, served as President during the year 1916–17, and was always deeply interested in the work of the Association.

Dr. Silver died at Orlando, Florida, March 22, 1946. His wife, Elizabeth Roadman Silver, survives him.

News Notes

REPORT FROM THE COMMITTEE ON POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY AND THE OFFICE OF ORTHOPAEDIC INFORMATION

Since the last report, made in *The Journal of Bone and Joint Surgery* (Vol. 28, pages 401–403, April 1946), the activities of this Committee and Office have continued.

As of June 1, this office has the names of 192 medical veterans who have been discharged from the Service and who are desirous of immediate training, and the names of eighty-five who are still in the Service, but expect to be discharged during 1946 and wish their training to start during the present year. This figure is to be compared to the last report of 220, an increase of fifty-seven. There are forty-eight men in the Service who have sent inquiries to this office and who desire training when they have been discharged, which will be after January 1, 1947. This office has been notified of only an occasional vacancy. One hundred and fifty-nine letters regarding vacancies have been sent to men desirous of training.

Since the last report, there have been thirty-seven additional orthopaedic services approved for training. This figure, added to the 110 previously approved, makes 147 single or combined orthopaedic services accredited for training at this time. Nearly all of the civilian hospitals, which formally applied for approval of orthopaedic training, have now been passed on by the Council on Medical Education and Hospitals of the American Medical Association and by The American Board of Orthopaedic Surgery. The number of approved residencies at the present time is approximately 453.

Since the April report, many of the Veterans Hospitals have established their Services, which are now in operation. There have also been approved Services established in six Army Hospitals, nine Naval Hospitals, and one Marine Hospital.

This office continues to have many inquiries from fully trained orthopaedic surgeons regarding locations for practice and from Diplomates of the Board looking for trained assistants. The Office of Orthopaedic Information will continue to carry on this phase of the work.

A. R. Shands, Jr., M.D., Secretary

June 1, 1946

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Spring Meeting of the British Orthopaedic Association was held at the Royal Victoria Infirmary, Newcastle-on-Tyne, on May 24 and 25, under the presidency of Mr. George Perkins, M. C.

The Robert Jones Prize for 1945 was presented to Mr. S. Pappworth, M. Ch. (Orth.), Sheffield, for his essay on "Primary Treatment of Lacerations of the Hand".

Mr. H. Jackson Burrows paid a graceful tribute to the Australian Orthopaedic Association, in whose Annual Meeting at Sydney he and his colleagues at the Royal Naval Hospital had been privileged to participate.

Mr. E. A. Nicoll reported upon 150 miners who had suffered fractures of the thoracic or lumbar spine, which he classified as (a) simple anterior wedge fracture, (b) lateral-marginal fracture (whose special features he defined), (c) fracture-dislocation, and (d) fracture of the neural arch. The results of simple wedge fractures did not depend necessarily upon the presence or absence of deformity. Hyperextension treatment would not promote repair of a concomitant injury of the intervertebral disc, and was itself often a source of chronic lumbar strain; consequently, Mr. Nicoll now preferred early exercises, with no more restraint than bed rest.

Mr. J. K. Stanger dealt with cases of fracture-dislocation of the spine, which occurred mostly in the thoracolumbar and mid-cervical regions. Paraplegia was commonest, with injuries at the narrowest parts. Recoverable cases of paraplegia could not be distinguished from those that were irrecoverable, and consequently reduction should be attempted. When open reduction was done in cases with locked facets, partial facetectomy was rarely required; and exposure might even reveal that spontaneous reduction had begun, only hyperextension being required for its completion. Although the results of open reduction in these cases with locked facets and paraplegia were exceedingly disappointing, and although closed reduction could be achieved, Mr. Stanger did not yet feel able to advocate closed reduction as the usual procedure. Fixation was by plaster jacket or, if posterior structures were fractured, by plaster bed. Redislocation, which was frequent, did not cause recurrence of cord symptoms and was often followed by bony ankylosis. The first evidence of recovery from paraplegia might appear as late as six weeks after the injury, and the extent of delay was no measure of the prognosis. Patients in various degrees of recovery after paraplegia from fracture-dislocation were shown.

Mr. W. Grant Waugh gave a restrained account of his studies of the pH of acute and chronic joint

effusions, and of his attempts to modify the pH by the injection of appropriate liquids. A clinical estimate was given of the results of treating the joints in osteo-arthritis and rheumatoid arthritis by intra-articular injections of a solution of lactic acid and procaine of approximately constant pH. The injections were followed by exercises and later by manipulations, which were facilitated by the injections and formed an integral part of the treatment. Procaine solutions were not a satisfactory substitute. Mr. Waugh asked for trial of the method by others. Some present were able to report encouraging results.

Mr. Pridie advocated excision of the calcaneus in very severe cases of comminution, and showed film strips to demonstrate the supple feet, good gait, and powerful plantar flexion which might follow this procedure, if continuity of tendo calcaneus and plantar fascia was maintained. He considered that the subcutaneous fibrofatty pad and the partially regenerated bone provided a serviceable heel. In the lively discussion which followed, the consensus was in agreement with Mr. Pridie's condemnation (following Eastwood) of immobilization of these fractures; strong in advocacy of early movement without weight-bearing; but condemnatory of so drastic an operation, and particularly of its performance through a longitudinal dorsoplantar incision.

Mr. E. W. Knowles had found that mid-tarsal dislocation might follow either a fall from a height or a torsion injury, such as that resulting from a fall with the fore part of the foot trapped. Reduction was very insecure. Consequently he advocated transfixion of the joint with a Kirschner wire, passed through the navicular and talus, and incorporated in plaster-of-Paris for four weeks.

Mr. J. B. Reid had investigated the results of McMurray's displacement osteotomy of the femur in osteo-arthritis of the hip and in ununited fractures of the femoral neck. Of thirty-six patients with osteo-arthritis, twenty-eight were completely relieved of pain. Among thirteen patients with ununited fractures, union followed in seven and one patient died.

Mr. P. H. Newman, D.S.O., M.C., discussed the clinical diagnosis of fat embolism, which had been frequent in war injuries and, if sought, would probably be found to be correspondingly frequent in civil life. Mention was made of the psychological changes, pyrexia, tachycardia, increased respiratory rate, raised blood pressure, petechiae of characteristic distribution, fundus changes, presence of fat in the last-voided urine, and the lack of information given by the sputum. The importance of efficient splinting and transport of patients with fractures was stressed. Mr. Newman had ligated the deep femoral vein in two cases, in one of which recovery occurred.

Mr. A. Graham Apley gave a preliminary demonstration of a test designed to aid discrimination between meniscal tears and sprains of the knee.

Clinical cases shown included unilateral adolescent coxa vara (slipped upper femoral epiphysis) in a father and each of his twin sons (by Mr. C. Gordon Irwin); tendon transplantations (by Mr. J. Gilmour and Mr. David Brown); melorheostosis and osteoid osteoma (by Dr. W. Mackenzie); and some results of nerve suture (by Mr. F. G. St. Clair Strange).

Mr. John Gull demonstrated an ingenious armchair for invalids, which would hoist the patient onto his feet in an upright position or, conversely, lower him gently into the sitting position, the power being provided by an electric motor.

At the business meeting, the following were elected to membership:

Full Members:

J. G. Bonnin, F.R.C.S., Newmarket
Major John Charnley, R.A.M.C.
B. Keon-Cohen, F.R.C.S., Melbourne
A. B. Pain, F.R.C.S., Leeds
I. S. Smillie, O.B.E., F.R.C.S., Edinburgh

Associate Members:

J. F. M. Frew, F.R.C.S.E., Aberdeen
George Hay, F.R.C.S.E., Brechin
L. Henry, F.R.C.S., Cheltenham
B. Isserlin, F.R.C.S.E., Bristol
Lionel E. Jones, M.S., F.R.C.S., Sutton, Coldfield
H. G. S. Korvin, F.R.C.S., Stoke-on-Trent
Walter Laurence, F.R.C.S.E., Oswestry
W. C. Lawrence, F.R.C.S.E., Coventry
H. B. Lee, F.R.C.S., London
R. N. Martin, F.R.C.S., Norwich
St. J. G. O'Connell, F.R.C.S.E., London
C. M. Squire, M.R.C.S., Chesham
Dr. Meriel Wagstaff, Bristol
M. E. Winston, F.R.C.S.E., Inverness

It was announced that the 1946 Annual Meeting would be held in London on October 18 and 19, and that the 1947 Spring Meeting would take place in Exeter.

Current Literature

CHIRURGIE DE LA MAIN: LIVRE DU CHIRURGIEN. CHIRURGIE RÉPARATRICE DES TRAUMATISMES DE LA MAIN. Marc Iselin. Paris, Masson et Cie, 1945. 145 francs.

One cannot help expressing a word of admiration for the energy and courage which impel men to stick to their appointed tasks when "the going is tough". One can visualize a few of the many difficulties that must have been overcome before this volume appeared in print, and everyone interested in the surgery of the hand will join in extending congratulations to the author on his achievement.

In a concise classification of the lesions which result from injury, Iselin divides them into four groups: those with loss of the hand or a part of it; those with digits rigid (*enraidis*) as a result of joint involvement; those with digits fixed by scar tissue (*bridés*); and those with loss of active movement, due to nerve or tendon injury (*inértes*).

After a brief discussion of the principles of splinting and of various forms of physical therapy, the author discusses, in turn, joint lesions, injuries and loss of the covering tissues, tendon injuries, and nerve injuries. In the three final chapters he considers the problems of painful stumps, of replacement of injured digits (with especial emphasis on the thumb), and of substitutes for the amputated hand.

In his discussion of tendon injuries (forty-eight pages of the total of 230), the author follows along the lines outlined in his earlier work on surgery of the hand. He gives credit to Bunnell for many of the fundamental principles described, and in the main the technical procedures described are well illustrated. One would be glad to see more illustrations of the results that have been achieved. In his discussion on re-formation of the thumb (thirty-three pages), the author includes illustrations from Sauerbruch, Lexer, and de Györ, in addition to several of his own. It is difficult, however, to convince oneself that the results obtained justify the extensive surgical procedures described.

Without agreeing with all the procedures and suggestions which Iselin recommends, one must recognize his serious and enthusiastic effort to raise the standards of surgical care for patients with hand injuries. For that effort he deserves every commendation.

A HISTORY OF MEDICINE. Douglas Guthrie, M.D., F.R.C.S. Ed., F.R.S.E. Philadelphia, J. B. Lippincott Company, 1946. $6.00.

It is difficult to comprehend the attitude of medical practitioners who are not concerned with the history of the profession which they have chosen to follow. There is, however, no doubt that this is the prevalent attitude. Possession of this volume of Guthrie's would do much to dispel this attitude, for it not only cites the development of the art of medicine as it took place in successive periods of the world's history and in the hands of different nationalities, but it brings into the picture the part played by the outstanding practitioners in those different periods in a way that makes the narrative more interesting than is often the case in medical histories. Toward the end of the volume the author deals with the rise of specialization and of preventive medicine, and finally devotes a number of pages to medical journalism and bibliography.

A feature that adds greatly to the value of the book and should encourage the reader to go further in his studies is the list of references which have furnished the material out of which this volume has been, to a considerable extent, compiled.

Everyone in practice, as well as those in the process of acquiring their medical training, should possess this book.

EL CODO SUS FRACTURAS Y LUXACIONES (The Elbow: Its Fractures and Dislocations). Antonio H.-Ros Codorníu. (Colección de monografías sobre ortopedia y traumatología, Vol. 2.) Madrid, *Cirugía del Aparato Locomotor,* 1945.

This is an exceptionally good monograph on the elbow, and would be in a leading position in any language. It is beautifully done, and the author has taken great pains to cover the subject completely.

Three chapters are given over to the embryology, anatomy, and biomechanics of the elbow. All of these subjects are discussed in great detail. The next ten chapters deal with specific types of fracture of the elbow, and they are treated according to anatomical types and regions. The author has a detailed classification of elbow-joint fractures, which is on a sound basis and easy to remember. In each type of fracture, the subject is treated under the headings of general considerations, physiopathology, pathogenesis, pathological anatomy, symptoms, diagnosis, treatment, and prognosis. Excellent illustrations, both drawings and roentgenograms, are presented. The author quotes end-result statistics, both his own and those of other authors, which greatly enhance the value of the book.

The author has the faculty of combining the qualities of a textbook with those of an advanced and interesting treatise. In general, the treatment of fractures of the elbow is along lines frequently used by American orthopaedic surgeons. Treatment is completely up-to-date. There is considerable

tendency to stress open reductions, in contrast to the extensive use of traction which was in favor some time ago Approaches for the various open reductions are dealt with in detail and are very well done

The author has a number of original ideas His method of holding complete fractures of the olecranon reduced during open reduction is by use of a heavy piece of wire, bent in the form of a very long staple with short points Roentgenograms illustrating his method show excellent reduction of the fracture and retention of the fragments In numerous other cases staples were used, as in the fracture of the trochlea, in which a very long, narrow staple was used Another of the author's original ideas is a somewhat complicated clamp for holding reduced badly comminuted or T fractures of the lower end of the humerus while internal fixation is being applied

The Monteggia fracture is treated as a separate entity, a whole chapter being devoted to it Another entire chapter is devoted to dislocations of the elbow, and a long and excellent chapter to reconstructive surgery of the elbow joint Posttraumatic ossification, nerve lesions, and Volkmann's contracture are all treated in separate chapters

Innumerable references to the literature are included, and many references to recent American publications were noted A good bibliography, divided according to subjects, is placed at the end of the book All in all, it is an excellent book and will prove of great value to its readers

Traitement orthopédique de la paralysie infantile (Orthopaedic Treatment of Infantile Paralysis) M Boppe Paris, Masson et C^ie^, 1944 140 francs

From the preface to its short terminal bibliography, this small monograph impresses the reviewer by its essential sincerity and good common sense It does not pretend to the dignity of a reference book, but it obviously represents the wide personal experience of the author in the treatment of all stages of infantile paralysis In all its phases, poliomyelitis is the orthopaedic disease *par excellence* With the exception of electrotherapy, all modalities of treatment—reeducation, mobilization (passive or instrumental), the making of braces, and surgical intervention—are strictly within the domain of the orthopaedic surgeon Although there is evidence in the book that the author is well aware of what is happening throughout the medical world, no mention whatsoever is made of Sister Kenny or the treatment which she advocates

Throughout this work, the author constantly stresses the importance of viewing the patient as a functional unit He believes that the orthopaedic surgeon who views his patient solely from the mechanical or morphological point of view often commits the worst of therapeutic errors It is not a question of what operation can be performed, but of what must be undertaken Boppe states that Nature, which we imitate, often finds a solution superior to that which we possess, and there are cases in which refusal to operate is more valuable than an aggressive therapy Conservative methods and the wearing of apparatus designed for temporary or permanent use is the keystone of therapy Surgery is to be employed principally in the last stage of the disease Surgical treatment has the sole objective of freeing the patient from the use of apparatus

With this point of view, the author divides his work into two parts The first part is concerned with such topics as the manner of examination, the prevention and treatment of poor positions, and the general treatment during the stages of recuperation and residual paralysis A chapter is devoted to a consideration of each of the following topics the paralytic foot, the paralytic knee, the paralytic hip, the paralytic trunk, the paralytic upper extremity, and the extensive monoplegias and paraplegias of the lower extremity The work is sparsely illustrated with line drawings and a few roentgenograms However, the text is so clearly thought out and so concisely expressed that the want of illustrations is not particularly felt

While it adds nothing new, this is such an excellent clinical monograph that both the student and the teacher will find it profitable reading

Surgical Treatment of the Nervous System Edited by Frederic W Bancroft, A B , M D , F A C S , and Cobb Pilcher, M D , F A C S , Philadelphia, J B Lippincott Company, 1946 $18 00

This outstanding work, to which contributions of chapters or sections have been made by seventeen well-known American surgeons and neurosurgeons, is a companion piece to Bancroft and Murray's "Surgical Treatment of the Motor-Skeletal System" It presents detailed and comprehensive descriptions of many special technical methods, and includes a consideration of the surgery of the various disorders and lesions which comprise the field of neurosurgery

A large proportion of the book is devoted to cranial and intracranial surgery, other sections deal with surgery of the spinal cord, surgical lesions of the peripheral nerves, surgery of the sympathetic nervous system, and the relation of chemotherapeutic agents to neurosurgery It has excellent illustrations including a few color plates

This is a carefully and critically prepared work, dealing with a complex and specialized field of surgery, but it will have great value for the general surgeon as well as for the specialist in the field of neurosurgery It cannot be recommended too highly

Penicillin Therapy and Control in 21 Army Group. Published under the direction of the Director of Medical Services, 21 Army Group, with Introduction by the Consulting Surgeon. Printing and Stationery Service, British Army of the Rhine, May 1945.

This book records observations and investigations carried out in British and Canadian hospitals of 21 Army Group in the European Theater throughout the Continental Offensive. It would appear that this was the first British Army group to receive unlimited supplies of penicillin,—sufficient for parenteral therapy. The various reports furnish an interesting sequel to the observations of Florey and Cairns upon the local use of penicillin.

Acknowledging the essentiality of primary surgery, the authors accredit penicillin as a major factor in the diminution of wound sepsis. Sulfonamides were found to be unnecessary, and an undesirable supplement to parenteral penicillin therapy in wound management. Penicillin was preferred by many surgeons for abdominal wounds.

The advantages of the parenteral route, even at the most forward surgical levels, were established. Supplemental local chemotherapy was widely used, especially for wounds of the knee joint and chest. A powder of calcium penicillin and plasma failed to prove effective in the local treatment of burns.

Penicillin is considered to have contributed to the expanded program of delayed primary suture: "Since the advent of penicillin the base hospital surgeon has become an animated sewing machine". The various contributors emphasize the technical details of wound management which are essential to success.

In summary, this volume records a series of "random samples", sufficient to grant significance to the general conclusion that parenteral penicillin therapy has contributed to a conspicuous absence of wound sepsis. The consideration of technical details of wound management further identifies these reports as important source material for the medical historian of World War II.

Accidentes vasculares de los miembros (Vascular Accidents of the Limbs). F. Martorell. Barcelona, Salvat Editores, S. A., 1945.

Martorell, as chief of the section in vascular surgery at the Polyclinic Institute of Barcelona, has had a wide experience in disturbances of the circulation. Many of these disturbances appear suddenly and lead to serious complications. For these, he considers the name vascular accidents to be most appropriate. The physiopathological mechanisms, the symptoms, and the treatment of these accidents are discussed. Arterial disturbances are discussed in Part I and venous disturbances in Part II.

The book has many excellent sketches, which show the circulatory disturbance at a glance. In addition, case histories accompany the sections on treatment. This is a very effective method of presenting the material. The book is written clearly. In addition to the sketches, there are many good pictures. An extensive bibliography is added.

An English edition of this work would be of great help, particularly to orthopaedic surgeons who see many disabilities associated with circulatory disturbances of the limbs.

Anatomical Atlas of Orthopaedic Operations. L. S. Michaelis, M.D. London, William Heinemann Ltd., 1946. 25 shillings.

This small book is based, quite properly, upon methods of approach and exposure. It is quite unambitious: detail is scanty; and alternative incisions, with their respective purposes and merits, receive only brief mention. It will be useful in helping the beginner to orientate himself, especially as there are references to original descriptions of operations; otherwise, it is in no sense a book of reference or an adequate guide to the aspiring orthopaedic surgeon. In short, it may be used as an early stepping stone to more thorough information.

Traitement chirurgical de l'arthrite sèche de la hanche. Suivi de travaux de la Clinique Orthopédique de la Faculté de Lyon (Surgical Treatment of Osteo-Arthritis of the Hip). L. Tavernier and Ch. Godinot. Paris, Masson et Cie, 1945. 150 francs.

This volume of over 350 pages is divided into three parts. The largest amount of space is devoted to the treatment of chronic osteo-arthritis of the hip, especially by the method of enervation. The second part takes up the surgical treatment of other joints. The third part is largely a compilation of abstracts of articles on the treatment of many other conditions,—such as scoliosis, protrusion of the disc, and osteosarcomata.

The first part presents an interesting review of the symptomatology and treatment of chronic osteo-arthritis of the hip. Treatment by means of subtrochanteric osteotomy, arthrodesis, and arthroplasty are reviewed hastily. In the unilateral cases, arthrodesis appears to be the operation of choice. The authors believe that it is a heroic method, but the most trustworthy in the treatment of arthritis of the hip. However, the possibility of bilateral involvement necessitates arthroplasty on at least one side. Of a series of seventeen cases submitted to arthroplasty, satisfactory results, both as regards relief of pain and range of motion, were obtained in twelve.

Subtrochanteric osteotomy should be reserved mainly for the correction of an awkward position.

Its use as a primary treatment in arthritis is not entirely satisfactory, because it leads to limitation of motion. The shelf operation is recommended only when the osteo-arthritis is secondary to a congenital dislocation of the hip. The authors stress the importance of creating the shelf at the level of the head, without traction. Drilling of the femur is useless, as it gives only temporary relief.

As a simple method of relieving pain, especially in those cases in which a more radical operation is contra-indicated, the authors recommend enervation of the hip.

The sensory supply of the hip joint is derived through the posterior division of the obturator nerve, the femoral nerve, and the sciatic nerve. The anatomy of the obturator nerve and of the articular branch of the sciatic nerve is discussed, and the technique of section of these nerves is described.

Of fifty-seven cases in which the obturator alone was resected, immediate relief of pain was obtained in forty-five, or 82 per cent. With the lapse of time, however, recurrences were observed in a number of these cases. Six patients could not be followed, but, of the remaining fifty-one, fourteen were completely successful and five showed marked improvement. Thirty-one had return of pain, and of those who submitted to a secondary resection of the sciatic nerve, seventeen were immediately relieved of pain.

The authors believe that this is the operation of choice in all cases in which the affection is bilateral or in which arthrodesis is contra-indicated. It is a simple procedure, which does not produce shock and does not reduce the range of motion in the hip.

The second part of the book is devoted to an application of the principle of enervation to other joints, such as the shoulder, the knee, the ankle, the wrist, and the toe. The specific nerve to be cut and the technique of exposure are described in each instance. The method is interesting and should have a definite field of usefulness where more specific therapy cannot be applied.

The Traumatic Deformities and Disabilities of the Upper Extremity. Arthur Steindler, M.D., F.A.C.S., in collaboration with John L. Marxer, M.D. Springfield, Illinois, Charles C. Thomas. 1946. $10.00

In these days when so much thought is being given to reconstructive surgery, this excellent book on traumatic deformities of the upper extremity will fill a real need.

The different disabilities of the upper extremity are grouped according to the type, nature, and extent of functional impairment, rather than by anatomical classification. Certain functional disabilities may result from different injuries. The plan of treatment may be similar, while the etiology of the traumata varied greatly. Moreover, accidents which appear very similar—such as fractures of a definite bone at the identical site—may result in deformities which are markedly different. Therefore, the emphasis has been placed on a functional classification of the conditions to be treated. It is recognized, however, that, from these unfortunate results, much can be learned about the value of the methods of the primary treatment.

Part A is devoted to general considerations of traumatic disabilities of the upper extremity. In Part B are discussed the traumatic disabilities of the special parts,—as Shoulder Girdle and Arm, Elbow Joint, Forearm and Wrist, and Hand and Fingers. Under each of these large sections are considered the various types of disability and deformity; for each of these types is presented the pathogenesis, symptoms, and methods of treatment. Then follow illustrative case reports of each condition described, with references to others in the literature. About 260 of these case reports are presented, drawn not only from the authors' wide experience, but also from current medical literature.

The book represents a vast amount of study and careful, analytical thought. The publishers have presented this material in most attractive form. Surgeons for years to come, who will find this book of practical help, will be indebted to Dr. Steindler and his associates for this painstaking work.

Pathology in Surgery. N. Chandler Foot, M.D. Philadelphia, J. B. Lippincott Company, 1945. $10.00.

Dr. Foot, who is Professor of Surgical Pathology at Cornell University Medical College, has made a careful selection of pathological conditions, which has resulted in a book that covers the subject adequately. His discussions are clear and are sprinkled with his characteristic whimsies. The volume is liberally illustrated, but the photomicrographs have not all been reproduced clearly; this is particularly true in the section on skin. The author's colored drawings might well have been omitted, for they undoubtedly added considerably to the cost of publication, without a comparable contribution to usefulness. The general format of the book is quite satisfactory.

The book opens with a chapter on technical and administrative suggestions for the surgical pathologist, followed by discussion of the basic principles of inflammation and repair and the general pathology of tumors. The remainder of the volume covers in a unique way the pertinent pathology of the tissues and organs, with emphasis, of course, upon those conditions with which the surgeon is especially concerned, including the nervous system and the skin.

This book is a convenient reference for the surgeon and for the hospital pathologist. It should prove valuable to both of these groups.

The Management of Fractures, Dislocations, and Sprains. John Albert Key, B.S., M.D., and H. Earle Conwell, M.D., F.A.C.S. Ed. 4. St. Louis, The C. V. Mosby Company, 1946. $12.50.

This excellent work by Key and Conwell, now in its fourth edition, is well on the way toward becoming a classic in its field. As compared with previous editions, the principal changes in the present volume occur in the sections on the hip, on injuries to the spine, and on the treatment of compound fractures and war wounds. A discussion of chemotherapy has been added as it affects various phases of treatment. Some of the old illustrations have been replaced, and new ones have been added. Methods of treatment which are considered obsolete have been omitted, and experience gained during the War has been included.

This book has earned and maintains an established position in a field in which good texts abound. The original statement of the authors — that it was "written for the student, the general practitioner, and the surgeon" — applies equally to the most recent edition.

Motor Disorders in Nervous Diseases. Ernst Herz, M.D., and Tracy J. Putnam, M.D. Morningside Heights, New York, King's Crown Press, 1946. $3.00.

Because orthopaedic surgeons are concerned primarily with disorders of the musculoskeletal system, this new textbook on motor disorders in nervous diseases will be of interest to them. According to the preface, the authors intended originally to make a group of films, suitable for teaching, on motor disorders caused by various nerve diseases. It became apparent that a syllabus to accompany the films would be of value, and eventually this syllabus was expanded and illustrative material was included by reproducing individual frames from the motion pictures.

The chapters on Involuntary Movements in Nervous Diseases, Disorders of Gait, Disorders of Coordination, Muscle Status, Reflexes, and Skilled Acts will be helpful to orthopaedic surgeons.

It is somewhat disappointing that the authors could not have analyzed, in more detail, disorders of gait caused by infantile paralysis and cerebral spastic paralysis. Due to the fact that the illustrations are taken from sixteen-millimeter motion-picture film, they are not of particularly good quality. However, they do present satisfactorily the various motor disorders as they occur clinically.

This volume will undoubtedly find its greatest usefulness as an introductory text for students of neurology and as a "refresher" for neurologists, neurosurgeons, and orthopaedic surgeons.

Hospital Care of the Surgical Patient. A Surgeon's Handbook. George Crile, Jr., M.D., and Franklin L. Shively, Jr., M.D. Ed. 2. Springfield, Illinois, Charles C. Thomas, 1946. $3.50.

The second edition of this timely handbook is more than a hundred pages longer than its predecessor. Part of this increase is due to the inclusion of an Appendix on the treatment of wounds, written by one of the authors and reprinted from Lewis' "Practice of Surgery". The material in the Appendix is in keeping with the rest of the volume, which is intended primarily for the use of surgical interns and house officers.

The authors deal with the physiological principles involved in the treatment of surgical patients, the treatment of the more common surgical complaints, and preoperative and postoperative care. There is an excellent and detailed section on the technique of common hospital procedures. A short section on the relation of the house officer to the patient and another in which dosages and diets are discussed close the main portion of the volume.

In general, the handbook serves its purpose well, and should be extremely useful as a guide to young surgeons and busy interns.

Preoperative and Postoperative Treatment. Edited by Lieutenant Colonel Robert L. Mason, M.C., A.U.S., and Harold A. Zintel, M.D. Ed. 2. Philadelphia, W. B. Saunders Company, 1946. $7.00.

The contents of this book of 584 pages are divided into two parts. Part I covers general preoperative and postoperative problems; Part II consists of similar discussions from a regional standpoint. Many of the chapters have been written by physicians who are recognized specialists in their fields. The subject matter represents, for the most part, the accepted teaching in Boston on each specific problem. The articles are amply and well illustrated.

Recent advances in surgical care have been rapid, due largely to utilization of applied physiology, biochemistry, bacteriology, and pharmacology. Accordingly, any authoritative consideration of surgical care must be recent. This necessitated rewriting practically every chapter in the first edition. This has been done with such meticulous care that the second edition will prove of great value to any physician who has to care for a surgical patient. Not only will he obtain invaluable aid on general problems, but he will also find helpful information concerning the specific region in which he may be interested.

Although, for the most part, the contents of this book present the teachings which Boston accepts in regard to surgical care, a notable exception is the chapter on burns. Extraordinary achievements which have resulted from studies of burns during the War are not reflected in this section. The statements on skin-grafting are particularly inadequate, because the Padgett dermatome and the very important grafts taken with it are not mentioned.

The book is concluded with a very useful Appendix, covering laboratory findings in the blood and urine in health and disease.

The Journal of Bone and Joint Surgery

THE MANAGEMENT OF PENETRATING WOUNDS AND SUPPURATIVE ARTHRITIS OF THE KNEE JOINT IN THE MEDITERRANEAN THEATER OF OPERATIONS

BY COLONEL OSCAR P. HAMPTON, JR.*

Medical Corps, Army of the United States

The purpose of this report is to present experiences in the Mediterranean Theater of Operations with penetrating wounds and superimposed suppurative arthritis of the knee joint, and to outline a regimen of management which proved highly effective for these conditions.

Penetrating wounds of the knee joint are serious wounds[20]. The damage done when the wound was received is immediately prejudicial to subsequent function of the joint, and, of greater importance, each wound is potentially a site of suppurative arthritis. Once established, suppurative arthritis endangers the limb, and even the life of the patient. Evidence of this is shown in the data supplied by Frankau in the British "History of the Great War" (World War I). In the early stages of that conflict, the death rate from wounds of the knee joint was very high; amputations were performed in 60 per cent. of the cases uncomplicated by injury to the bone, and at least 80 per cent. of the patients with injury to the bone suffered the loss of the extremity. With improved methods of management, the amputation rate fell to 25 per cent. in 1916 and to only 7 per cent. in 1917, while the death rate declined to 8 per cent. Buxton, reporting 273 wounds of the knee joint treated in a Base Hospital during two Libyan campaigns in World War II, cites incidences of 34.8 per cent. suppurative arthritis, 4.4 per cent. amputation, and 1.8 per cent. mortality. These data established the fact that wounds of the knee joint are among the most serious injuries a soldier may receive.

Prior to the invasion of North Africa, several authorities[7,17,24,35] had recommended similar plans of management for wounds of the knee joint which were seen early; these plans consisted of the surgical removal of foreign bodies, foreign material, and loose chips of bone and cartilage, thorough lavage, and closure of the synovial membrane or capsule, followed by immobilization. A thorough sprinkling of one of the sulfonamides into the joint also had been suggested[24].

The value and necessity of closing the joint in the surgical treatment of these wounds have been stressed repeatedly. Pool attributed the poor results in wounds of the knee joint in the early part of World War I, in part, to "an undervaluation, on the part of surgeons, of the resistance to infection which the synovial membrane of a joint offers". Other writers[5,8,10,22] have emphasized the apparent bactericidal or bacteriostatic property of the synovial fluid. With the joint closed, this property was considered more effective, the

* Dr. Hampton entered military service from the Department of Surgery of Washington University, St. Louis, and since his return is again associated with that Department.

hazard of secondary intra-articular infection was obviated, the articular cartilage was not left exposed, and a greater return of function could be expected.

For wounds seen late or after sepsis had become established, these authorities recommended that closure of the synovial membrane be omitted, because closure was in direct conflict with the accepted principles of drainage for infected knee joints. This modification of the regimen for cases seen late was recommended, despite the observations of Pool in World War I and of others[16,23,25,30,35] in the early phases of World War II that, after the joint cavity had been cleaned thoroughly, closure of the synovial membrane was permissible and was indicated for as long as twenty-four hours after the wound had been received.

Although adequate drainage has remained a fundamental principle of the treatment of suppurative arthritis of the knee joint[1,3,12,19,26] since World War I, the highly heralded Willems treatment[9,36], consisting of forced active motion combined with drainage, which was advocated during that War, has not maintained favor[28] and has been generally discarded, in spite of the fact that Steele stressed its advantages in 1929. In World War I, Abbott utilized a posteromedial incision for drainage of the knee joint; since then, Henderson, Babcock, and Orr have recommended posterior incisions for this purpose. Parapatellar incisions, however, have been employed most generally[3,9,12,14,17,19,25,26]. Immobilization in a Thomas splint or in plaster, after drainage had been established, has been customary. The same authorities, who recommended the plan of management for penetrating wounds of the knee joint which has been outlined here, also recommended drainage for superimposed sepsis which had become established in the joint. During and since World War I, the value of combining irrigations of chemical solutions with drainage has been stressed[5,6].

In contrast to open drainage, some authors[6,31] recommended aspiration of the joint fluid in cases of blood-borne suppurative arthritis; for this condition, Jones recommended a small arthrotomy incision, thorough lavage, and then closure of the joint. These procedures, however, were not recommended for suppurative arthritis complicating intra-articular wounds.

The reported results in cases of suppurative arthritis of the knee joint, following wounds caused by missiles, were far from encouraging in World War I [11,16] and in the early part of World War II [2,23,25,32]. In spite of what appeared to be adequate drainage, in many cases the ravages of sepsis led to amputation of the limb or to death. Even if these misfortunes were avoided, many joints became totally destroyed by the septic process and fusion resulted. Ogilvie, although recommending drainage for patients with suppurative arthritis, stated that the battle against sepsis was usually decided within four days; if the septic process was not controlled in that time, amputation was usually necessary to save life.

The French, in the last part of World War I and in the early phases of this War[30], had accepted the belief that, once suppurative arthritis had become established, the joint was doomed and the patient's life was endangered. Fear of such dire consequences led them to adopt primary resection as a prophylactic measure in the patient with a severely damaged joint—recognized as especially vulnerable to sepsis—and secondary resection as a therapeutic measure for acute suppurative arthritis, if the infection failed to respond quickly to long anterolateral incisions and thorough immobilization. Pool recommended resection for suppurative arthritis which was superimposed on a severely damaged joint. French, Russian[21], and German[16,23,32] surgeons practised resection extensively throughout World War II, rather than risk the hazards of suppuration of the knee joint.

Early in the experience in North Africa, it was seen that penetrating wounds of the knee joint could be classified roughly, according to the severity of damage to the intra-articular bone and cartilage, into three groups:

Group A: Wounds in which there had been no damage to the bone or cartilage;

Group B: Wounds involving minimum or moderate damage to portions of the condyles of the femur or tibia;

Group C: Wounds involving severe destruction of the joint components.

While the results varied somewhat in 1943 during the Tunisian, Sicilian, and early Italian Campaigns, according to the degree of intra-articular damage, it appeared that the surgical management of the case also had a direct effect. The recommended plan of arthrotomy, intra-articular débridement, lavage, closure of the synovial membrane, and immobilization in a toe-to-groin plaster cast was usually followed in the forward hospitals for wounds of the knee in Groups A and B. If, however, the surgical treatment was delayed for more than eight to twelve hours after the wound had been received, or if there was sepsis of the joint, closure of the synovial membrane was omitted in order to permit drainage. In the cases in Group C, the wounds were often extended and were always left open for drainage, but extensive intra-articular débridement was not performed.

Suppurative arthritis in Group A (those cases without bone or cartilage damage) was seldom, if ever, observed; and it was rare in Group B (the cases with minimum or moderate damage within the joints). In these favorable cases, however, it was noted that, if closure of the synovial membrane had been omitted, healing was often slow and the subsequent joint function was frequently limited beyond that to be expected from the wound damage. In other cases of Group B, there was lingering sepsis and slow destruction of the joint. Although in these cases the joints were the sites of suppurative arthritis, the open drainage sufficed to prevent systemic sepsis and toxaemia. Obviously, the joint was doomed. Unfortunately, no data on the incidence of this complication are available, but the observation was general, and confirming reports reached the Theater from the Zone of the Interior. In Group C, which included the joints with severe destruction, septic arthritis was the rule. In each of these patients, the joint had been destroyed when the wound was received, and an ankylosed knee was the best that could be expected. Although it was recognized that the joint was destroyed and that suppuration was likely, resection, as practised by the French in this type of injury, was not considered. Fortunately, no deaths were reported, and only a few amputations were necessary.

During the Cassino-Anzio impasse, in the several Base Hospitals in Naples, a sharp rise was noted in the incidence of suppurative arthritis. This rise was coincident with a wave of surgical conservatism among the forward surgeons at the Anzio Beachhead, accounted for, at least in part, by the conditions under which they were working, and resulting in a minimum of exposure and intra-articular débridement. The increased incidence of suppurative arthritis focused attention upon the problem of wounds of the knee joint and their complications, and permitted the following study:

MATERIAL

Nineteen patients having wounds of the knee joint, with potential, early, or late sepsis within the joints, were studied closely; and data on them were compiled, in conjunction with the formative stage of a program for the adjuvant use of penicillin in the management of the wounded. Approximately thirty-five other patients were also observed and studied, but no data were gathered. Both groups of patients had been wounded; they had received initial surgical treatment in the forward hospitals a few days or a few weeks before, and had been transferred to Base Hospitals.

No sepsis of the knee joints was observed during this study in those patients treated by complete initial surgery, closure of the synovial membrane or capsule of the joint, and adequate immobilization[34]. Of course, this was a highly significant observation. Definite suppurative arthritis of all degrees of severity, with prolonged drainage and slow destruction of the articular surfaces, was observed in several patients whose joints had moderate or even minimum intra-articular damage, but where the excisional surgery had been poor and the joints had been left open for drainage. Compound, comminuted fractures of the patella were noted as the source of sepsis in several cases.

A particularly pertinent observation—made in several other cases of severe sepsis (not included in the nineteen observed closely) by the Surgical Staff of the Ninth Evacua-

tion Hospital[31], and confirmed in this study in approximately fifteen patients with sepsis of the knee joint of varying severity—was that each had unexcised, traumatized, devitalized, articular cartilage. Therefore, thorough and complete initial intra-articular surgery had not been performed.

An aggressive surgical regimen was instituted in each of the nineteen patients under close observation; antibacterial agents and whole-blood replacement were used as adjuvants. Penicillin, in doses of 25,000 units intramuscularly every three hours, was employed until the danger of continuing sepsis was past, and usually until all the wounds had healed. The local instillation of 1,000 units per cubic centimeter was supplemental. Blood transfusions were given in amounts which maintained a hematocrit level of at least 40 per cent. of red cells. Each joint was immobilized after surgical treatment by a single hip spica or by a Tobruk splint, until it was certain that all danger of a flare-up of sepsis was past and that the wounds were healing. Then the joints were mobilized.

Eight knee joints with evidence of intra-articular trauma, in which there had been only minimum exposure at the time of the initial operation, were reopened to be sure that the excisional surgery had been adequate, even though no definite signs of infection were present. In four cases, potential foci of sepsis, in the form of unexcised, devitalized areas of articular cartilage, were found and were removed. After thorough irrigation, the joints were closed, penicillin was instilled into the joint cavity, and immobilization was provided. No suppurative arthritis followed and function of the joints, limited only by the trauma associated with the wound, was obtained (Case 1).

Six knee joints with definitely established suppurative arthritis, but without septic destruction of the joint, were opened widely. The joint was cleaned of all devitalized tissue, debris, and foreign material; blood clot and pus were removed by thorough irrigation. The synovial membrane was sutured. Penicillin was instilled and immobilization was provided. Aspiration, irrigation, and reinstillation of penicillin were performed at intervals of twenty-four or forty-eight hours for about a week. Very little fluid reaccumulated, however, and the attempts at aspiration were usually unsuccessful. The sepsis was controlled, and function of the joint, limited only by the damage caused by the missile which produced the wound, resulted in every case (Cases 2 and 3).

Subacute septic processes of several weeks' duration in two other knee joints—one associated with a comminuted fracture of the patella and the other with a septic fracture of the lower third of the femur, which dripped pus into the joint—also were treated surgically. At arthrotomy, the necrotic areas of articular cartilage (produced in each case by the septic process and not by the missile) were removed with the curette, and the edges were trimmed of loose tags. The comminuted patella in the first case was completely excised. Both menisci in each knee were devitalized and friable; they, too, were removed. After thorough cleansing of the joint by irrigation, the synovial membrane was closed and the usual regimen was instituted. In both cases the sepsis was controlled, and delayed skin suture produced prompt wound healing. In each case, a fractured femur, associated with sepsis, handicapped a program for knee motion. However, from 10 to 20 degrees of motion was present in each knee joint when the patients were transferred to the Zone of the Interior (and also at a later check-up) (Case 4).

Limb-endangering sepsis in three knee joints was eradicated by resection of the joint. In one, associated with a contralateral amputation in the upper third of the thigh, the sepsis was so severe as to endanger the patient's life (Case 5). This condition had resulted from infection of a relatively innocent-appearing, but poorly debrided, compound fracture of the medial tibial condyle, with a line of fracture extending into the joint. In these three knee joints, treated by excision of the infected necrotic bone and cartilage, by resection, and by staged procedures directed at wound healing, sepsis was controlled, the wounds healed, and bony fusion was progressing at the time the patients left the Theater (Cases 5 and 6).

In six French Colonial soldiers, whose knee joints were the sites of severe suppurative arthritis, resection of the joints was performed during the same period by surgeons at the Ninth Evacuation Hospital[1] (which served as a Base Hospital for the French in the Naples Medical Center). The arthritis had developed after relatively minor damage of a typical penetrating wound, and, as stated previously, all of these patients received incomplete initial surgery. The sepsis in each knee joint definitely endangered the patient's limb. An amputation had been performed previously for comparable sepsis in a seventh case. In this group of patients, the wounds had healed and the knee joints were fused prior to transfer to the French hospitals in North Africa.

Consideration of the previous experience and of the observations made in these cases, which were studied carefully, led to the standardization of a plan for the management of all knee-joint wounds—penetrating or perforating, due to shell fragments or bullets—in the forward and base areas, regardless of the time which had elapsed since the wound was received. The objectives of this plan were the prevention of sepsis, the elimination of early established sepsis, and the optimum preservation of joint function.

A. *Forward Area*

Following adequate preparation by transfusions of blood or plasma and by appropriate roentgenographic studies, the patient was removed from the litter and placed on an operating table which permitted automatic angulation opposite the knee in order to facilitate intra-articular exposure. The skin preparation and draping were circumferential. A tourniquet often was applied to secure a dry operative field. The joint was opened to the extent and in the location which provided the best access to the intra-articular damage. A separate, standard arthrotomy incision was frequently necessary. Good light, assistance, and retraction were essential. Foreign bodies and other material were removed. Loose bone chips, areas of loose or devitalized cartilage, and damaged menisci were excised. The removal of devitalized, fragmented articular cartilage was considered exceedingly important. Defects in the condyles were trimmed evenly. A comminuted patella usually was excised. Thorough irrigation of the joint cavity completed the excisional surgery. The synovial membrane and, at times, the capsule were sutured; and from 10,000 to 20,000 units of penicillin was instilled into the joint cavity. Indirect injuries produced by fractures extending into the joint were managed similarly to ensure that no debris, loose fragments, or large blood clots remained. When loss of soft tissue precluded closure of the synovial membrane or capsule, it was desirable to rotate flaps of fascia or skin in order to achieve the desired closure (Case 7). An open joint was accepted only when the extent of the damage made it certain that the return of joint function was impossible. In these cases, it was preferable and often practicable to excise the remaining articular cartilage. The remaining joint injury could then be likened to a compound fracture. By excision of the remaining articular cartilage, a poorly nourished and avascular potential nidus of sepsis was removed.

The immobilization was accomplished by means of a single hip spica or a Tobruk splint, with the knee in from 10 to 15 degrees of flexion. Systemic penicillin therapy was given routinely. Twenty-four to forty-eight hours after the initial surgery, with the use of a large needle, the synovial fluid was aspirated, and the joint was irrigated and filled with penicillin through a window in the cast, preferably without exposure of the open wound or the arthrotomy incision.

The plan of management was applied regardless of the time interval between occurrence of the wound and surgical treatment, or the presence of established sepsis. However, thorough excisional surgery within the joint was prerequisite to success.

B. *Base Hospital*

At the time of reparative surgery, four to six days after the wound had been received, the joint fluid again was aspirated, the cavity was irrigated, and penicillin was reinstilled.

The open soft-part wound was sutured. If reasonable doubt existed concerning the thoroughness of the initial operation, the joint was opened and examined as a precaution against sepsis (Case 1). Following thorough cleansing, the joint, and usually the skin, were closed. If reparative surgery was delayed for any reason, the joint fluid was aspirated through the window in the cast, while the patient was on the ward.

Immobilization was discontinued within ten to fourteen days after secondary suture, and active mobilization of the joint was instituted, usually by means of balanced suspension in a Thomas splint with the Pearson attachment. The motion was progressively increased from the position of full extension, thereby avoiding flexion contracture.

Signs of impending or of established sepsis within the joint—such as pain, swelling, fever, and malaise—were indications for early surgical treatment. Occasionally, in cases which presumably had been properly managed at the time of initial surgery and had minimum signs of infection, the aspiration routine was employed for a day or two with the anticipation of avoiding the impending sepsis. Otherwise the joint was opened widely, thoroughly cleansed of dead tissue and blood clot, closed, filled with penicillin, and immobilized (Cases 2 and 3). The skin was not sutured, but the edges often were freshened in anticipation of a staged closure, five or six days later. Frequent aspirations, irrigations, and reinstillations of penicillin appeared to be important in the subsequent care. Again, only when hope of a functioning joint was abandoned was the joint incision left open for drainage, and then radical resection was usually preferable.

RESULTS

Excellent results were achieved throughout the Theater when this program was followed[13]. From the beginning of the Cassino-Rome campaign, in May 1944, until cessation of combat, the incidence of knee-joint sepsis was negligible, and the problem was relegated to a place of relatively minor importance. In the few cases of early sepsis of the knee joint, observed in the base area, appropriate surgical treatment and management controlled the process, and usually good function of the joint resulted (Cases 2 and 8). Chronic sepsis rarely was seen,—usually only in joints hopelessly destroyed by trauma. In a study of Disposition Board Proceedings on a sample of 1,073 amputations, Rawles found none resulting from sepsis of a knee joint *per se*.

Knee joints which had been hopelessly destroyed at the time the wounds were received were usually resected to prevent chronic sepsis and to promote early healing of the wounds (Case 6). In the occasional case in which sepsis of the joint developed in the Base Hospital, the sepsis was controlled and wound healing was achieved by resection. The extent of bone loss and destruction incident to the sepsis or the trauma determined the amount of bone excised and the resultant shortening. The resected surfaces were designed so as to conform with the knee in extension, rather than in some flexion, because of the shortening incident to the procedure.

Data on Results

Harris and Mollin reported* that, in 128 patients with wounds of the knee joint who received complete initial surgery in forward hospitals, 119 were recorded as free of sepsis at the time of inspection in the Base Hospital; and repair of the remaining wounds of the soft parts was permitted. In seven of the remaining nine cases, sepsis was controlled and a functioning joint was obtained; only the aspiration routine was utilized in four cases, secondary arthrotomy and excision of the intra-articular devitalized tissue were carried out in two cases, and incision and drainage in one. In the remaining two cases the joints were the sites of severe bone damage, with superimposed sepsis. One case was managed, and the sepsis was overcome, by resection of the joint. In the other case, damage to the extremity was so severe that amputation was performed. The initial surgical procedure

* Data compiled in June 1945, from the records of the Seventeenth General Hospital.

was judged, from the records, to have been incomplete in sixty-six additional wounds of the knee joint seen at the same hospital. Among these, sixteen patients with septic joints were found at the first inspection. The sepsis was controlled in eight cases by arthrotomy and a secondary débridement of the joints. One patient, with associated severe bone damage, responded to prolonged drainage through an open wound, but it was questionable whether any joint function was obtained. In the remaining seven cases, the joints were hopelessly destroyed by the trauma received at the time of injury. Five were successfully managed by joint resection. The bone destruction was so severe in two that amputations were performed.

The Surgical Consultant of the Seventh Army, Colonel Frank Berry, who formerly was the Chief of Surgical Service of the Ninth Evacuation Hospital, instituted the same program of initial surgery in hospitals of the Seventh Army. From two General Hospitals supporting the Seventh Army, he received reports that, over a three-month period, no sepsis of the knees had resulted following adequate initial surgery[27]. The first hospital had received eighty-three consecutive patients with penetrating wounds of the knee, without the necessity of amputation, resection, or drainage. In a comparable number at the second General Hospital, only four resections were performed,—three for traumatically destroyed joints, and one for established sepsis; this developed in a patient with severe abdominal injuries and a penetrating wound of the knee, which had been overlooked during a ten-day stay in a forward hospital.

Disposition Board Proceedings on file in the Office of the Surgeon, Mediterranean Theater of Operations, on a sample of 271 wounds of the knee joint, were studied by Duncan and Rawles. The cases were divided into Group A, those occurring prior to May 11, 1944, and Group B, those occurring later. On May 11, the final drive for Cassino and Rome was begun and, by that time, information as to the recommended program for the management of wounds of the knee joint had been disseminated throughout the Theater.

TABLE I

	Number	Per Cent.
Group A (prior to May 11, 1944)		
Non-septic	53	72.6
Septic	20	27.4
Totals	73	100.0
Group B (after May 11, 1944)		
Non-septic	188	94.9
Septic	10	5.1
Totals	198	100.0

The incidence of sepsis after admission to the Base Hospital was 27.4 per cent. in Group A, but only 5.1 per cent. in Group B. The septic process continued and destruction of the joint resulted in 8.2 per cent. of the cases in Group A; the end results could not be determined in another 8.2 per cent. In Group B, however, the septic process was uncontrolled in only four cases (2 per cent.). In three of these cases, the management recommended for early sepsis was not instituted. In the other case, the damage was severe and resection of the knee joint was performed.

Twenty-four resections of the knee joint in American soldiers and one resection in a Canadian soldier are known to have been performed in the Mediterranean Theater of Operations. Two resections were performed at the time of the initial surgical treatment because of severe trauma; twenty-three were performed at the Base Hospital. In three cases, previously described, the indication for the resections of the knee, which were performed during the formative phase of the program, was severe purulent arthritis, superimposed on moderate intra-articular damage in two instances and on minimum damage

in another. In the remaining twenty cases, the indication was traumatic destruction of the joint with impending or early sepsis. Among the twenty-five Americans and six French patients[1] whose knees were resected, there were no deaths or amputations. The general condition of each patient improved rapidly. Healing of the wound was achieved in the majority of the Americans before their evacuation to the Zone of the Interior. Three are known to have had healed wounds and clinically stable knees prior to their departure from this Theater. The resultant shortening varied from one inch to three inches, *and was in direct ratio to the bone loss from trauma or sepsis.* The average shortening was about one and one-half inches. Apposition of bones in a functional position was achieved without difficulty.

The management of knee-joint wounds in all phases conformed to every principle of initial and of reparative surgery,—that is, the removal of foreign bodies and the excision of dead tissue, including the destroyed articular cartilage and the contaminated blood clot; closure of the joint to protect the articular cartilage from the hazard of exposure and the synovial membrane from recontamination; the use of antibacterial agents to protect living tissue from invasive infection; thorough immobilization, by means of a hip spica or Tobruk splint, until the hazard of infection was over; delayed wound closure; and early restoration of function.

This experience confirmed previous observations on the proper management of wounds of the knee joint, seen early and without infection. The same principles and plan of management have been adapted to wounds seen late and to those in which sepsis has become established. The success achieved warrants the recommendation of the program for wounds of the knee joint, regardless of the time which has elapsed since injury or the presence of infection. It is believed that the same principles are applicable to suppurative arthritis—traumatic, postoperative, or blood-borne—in civilian practice.

CASE REPORTS

CASE 1. This patient was wounded on March 26, 1944, by multiple small-arms fire.

Diagnosis

1. Compound, comminuted fracture of the distal third of the right femur, with laceration of the bursa of the knee joint;
2. Compound, comminuted fracture, incomplete, of the middle third of the right tibia;
3. Compound, comminuted fracture of the lower pole of the left patella;
4. Compound, comminuted fracture of the left medial femoral condyle.

Initial Surgery

Fourteen hours after the injury was received, all the wounds were debrided. The wound of the right thigh was perforating; that of the left knee was penetrating. A partially severed medial patellar retinaculum was repaired with a wire suture. Both joints were irrigated. A bilateral hip spica was applied.

Record at Base Hospital

The patient was admitted on March 31, five days after injury. Penicillin therapy, 25,000 units every three hours, was instituted. Blood transfusions, totaling 3,400 cubic centimeters, were given over a three-day period.

Reparative surgery was carried out on April 4. Arthrotomy of the left knee was done, using a medial parapatellar incision. The medial femoral condyle had been perforated. The devitalized articular cartilage, which had been driven in at the time of injury, was excised; and several small fragments of the patella were removed. After thorough irrigation, the joint was closed and penicillin was instilled. The skin was closed so as to leave a small fine-meshed gauze drain emerging from the lower pole of the compounding wound.

Through the compounding wound of the right lower thigh, it could be determined that no articular cartilage was damaged. Several loose chips of bone were removed from the fracture site. The joint bursa could be only partially closed. The medial wound was closed completely and the lateral wound was closed partially, drainage being established through the dependent pole. The compounding wound of the tibia was small, without exposed bone; it was not sutured. A toe-to-groin cast, with a horizontal cross-stick to prevent rotation, was used on the left. The right femur was placed in skeletal traction and the

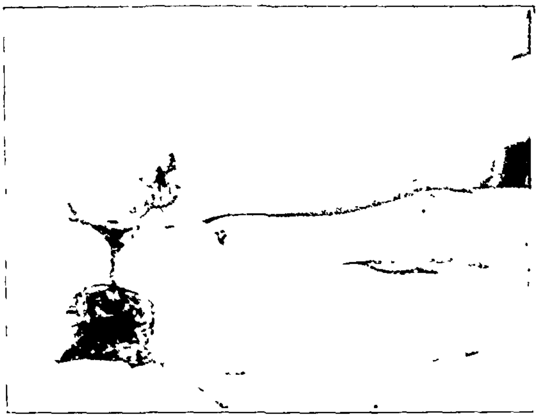


FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. The wounds of each extremity are shown, as seen in the operating room on April 4, 1944.
Fig. 1-B: Arthrotomy of the left knee, demonstrating part of the intra-articular damage. A defect on the weight-bearing surface is not shown.

FIG 1-C

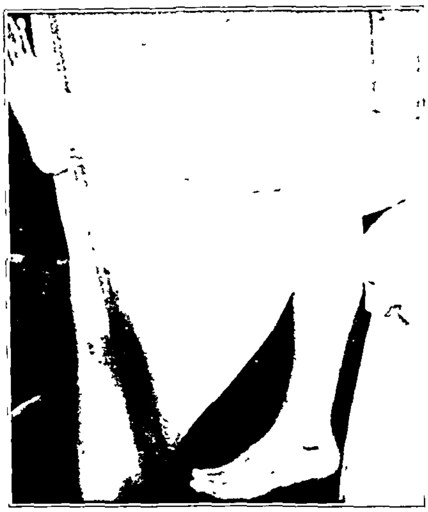


FIG. 1-D

Fig. 1-C: Closure of arthrotomy incission and wound of left knee, and drainage of the knee with fine-meshed gauze. Penicillin is being instilled.
Fig. 1-D: Shows range of motion of left knee in June 1945.

fragments were manipulated into reduction on the ward, before the patient had recovered from the anaesthetic.

The wounds of the left knee healed. Immobilization was discontinued about May 1, after being used longer than is considered desirable. The range of flexion improved quite slowly, and was only 25 degrees when the patient was evacuated to the Zone of the Interior.

The wounds which connected with the right knee joint healed, but there was prolonged drainage from sepsis in the cancellous bone of the lateral condyle of the right femur. Despite the sepsis, the fracture united in good position. The knee joint was free of suppuration.

Record at Zone of the Interior

When the patient was admitted on September 8, there was profuse discharge from the site of the fracture of the right lower femur. All the other wounds had healed. The fractures of the femur and of the right tibia were stable. Knee motion on the left was from 180 to 130 degrees, but it was practically nil on the right.

After appropriate surgical treatment, healing of the compounding wound of the right femur occurred. On June 27, 1945, knee motion in the left side was from 180 to 90 degrees, and on the right side it was from 180 to 120 degrees.

Comment

By thorough management of the rather severe wound of the left knee joint, healing and over 90 degrees of knee motion were obtained. The dead space in the cancellous bone was the site of sepsis, but good drainage and maintenance of reduction of the fracture were followed by union of the fracture in good position. The end result was satisfactory.

CASE 2.* The patient was wounded on October 6, 1944, by a high-explosive shell fragment.

Diagnosis

1. Penetrating wound of the right knee joint;
2. Compound, comminuted fracture of the right patella;
3. Early suppurative arthritis of the right knee joint.

Initial Surgery

Ten hours after injury, the joint was opened by enlarging the wound compounding the comminuted patella, the foreign body was removed, the joint was irrigated, and the capsule was closed. The comminuted patella was not removed. Penicillin was instilled into the joint, and systemic penicillin therapy was instituted. A mid-thigh cast was applied.

Record at Base Hospital

The patient was admitted on October 11. Systemic penicillin therapy was continued, but the joint fluid was not aspirated nor was penicillin reinstilled. The patient's temperature ranged between 99 and 101 degrees. On October 20, the knee was painful, swollen, boggy, and tender. On October 21, the old wound was excised to the depth of the fascia. The joint was open through the fractured patella. A separate medial arthrotomy incision was used to expose the joint, from which a small piece of woolen cloth and the severely comminuted patella were removed. The cartilage of the patella was yellow and gray in color. One fragment appeared necrotic. Gelatinous fibrinous exudate was cleaned from the joint and from the suprapatellar pouch.

After thorough irrigation, the synovial membrane was closed, and a few sutures were placed in the quadriceps expansion. The defect in the tendon, at the site of the old wound, was closed. The joint was filled with penicillin. Immobilization was provided by a Tobruk splint. On October 22, 24, 25, and 26, the joint was irrigated and filled with penicillin through a large needle. On October 26, the skin of each wound was sutured. Penicillin therapy was discontinued on October 29. About November 7, active knee motion was begun, only night splinting being used. On November 17, all wounds had healed, the joint was not swollen, quadriceps power was fair, and 45 degrees of active knee motion was present.

FIG. 2-A

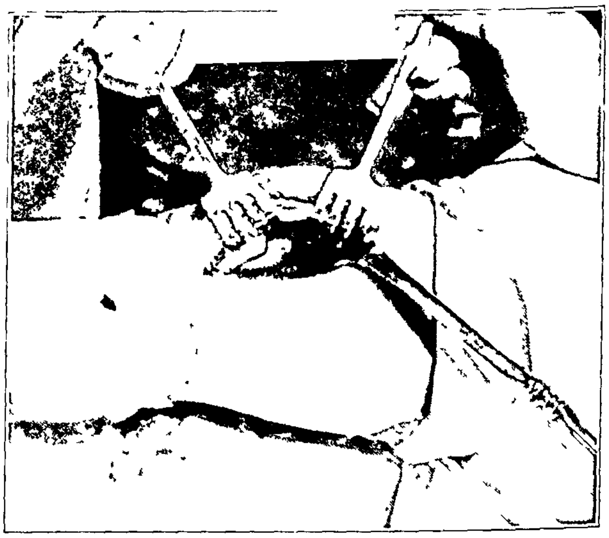


FIG. 2-B

Fig. 2-A: Case 2. Shows the swollen joint and the granulating wound, with pus draining from the opening in the center, as they appeared in the operating room on October 21, 1944, fifteen days after the wound had been received.

Fig. 2-B: Photograph of the medial arthrotomy incision. Inflamed synovial membrane and the partially necrotic cartilage of the comminuted patella are poorly visualized. The small piece of woolen cloth is shown on the gauze at the left of the incision. The quadriceps pouch was filled with a coagulated fibrinous exudate.

* This case was managed in the Base Hospital by Major John Abele of the Forty-Sixth General Hospital.

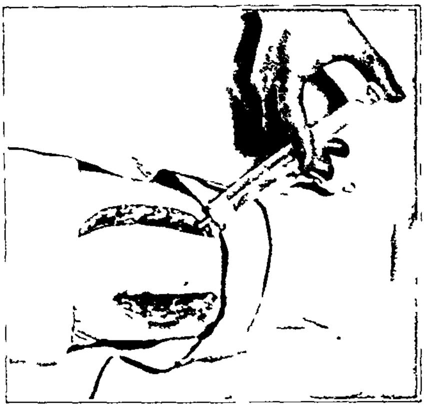
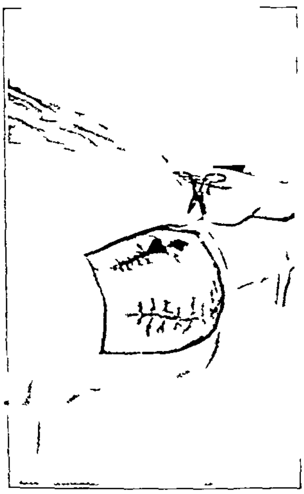


FIG 2-C FIG 2-D

Fig. 2-C: Following removal of the patella and cleansing of the joint, the synovial membrane of the arthrotomy incision and the defect in the old wound were sutured (plus a few sutures in the tendon). The joint was filled with penicillin.

Fig 2-D. The fragments of patella, some of the fibrinous exudate, and the bit of cloth removed from the joint are shown.



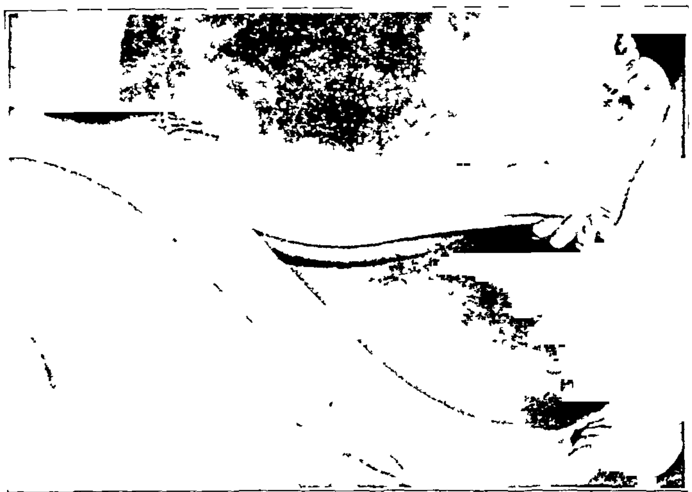


FIG 2-E FIG 2-F

Fig 2-E The skin has been sutured and the joint resplinted (October 26)

Fig 2-F Demonstrates the range of active painless motion of the knee on November 17 Quadriceps power was sufficient to extend the knee, but a hand held the foot for the photograph

Comment

A compound, comminuted patella was frequently a nidus of knee-joint sepsis prior to the standardization of the Theater program for wounds of the knee. Traumatized cartilage remains, and, obviously, the joint remains open The ineffectiveness of penicillin therapy when excisional surgery is inadequate should be noted.

In this case, removal of the comminuted patella and thorough cleansing from the joint of all foreign material, blood clot, and pus *before* proteolytic digestion of the articular cartilage began, followed by adequate immobilization and penicillin therapy, resulted in function of the joint.

This case is an excellent illustration of the management of *early* sepsis of the knee joint, which is a major contribution of this Theater in the management of wounds of the knee joint.

CASE 3. The patient was wounded on March 29, 1944, by multiple high-explosive shell fragments.

Diagnosis

1. Penetrating wounds of the left knee joint, left forearm and arm, and right foot;
2. Early suppurative arthritis of the left knee joint.

Initial Surgery

The wounds of the soft parts were debrided and foreign bodies were removed. For some unknown reason, possibly because of the multiplicity of the penetrating wounds, the knee joint was not opened.

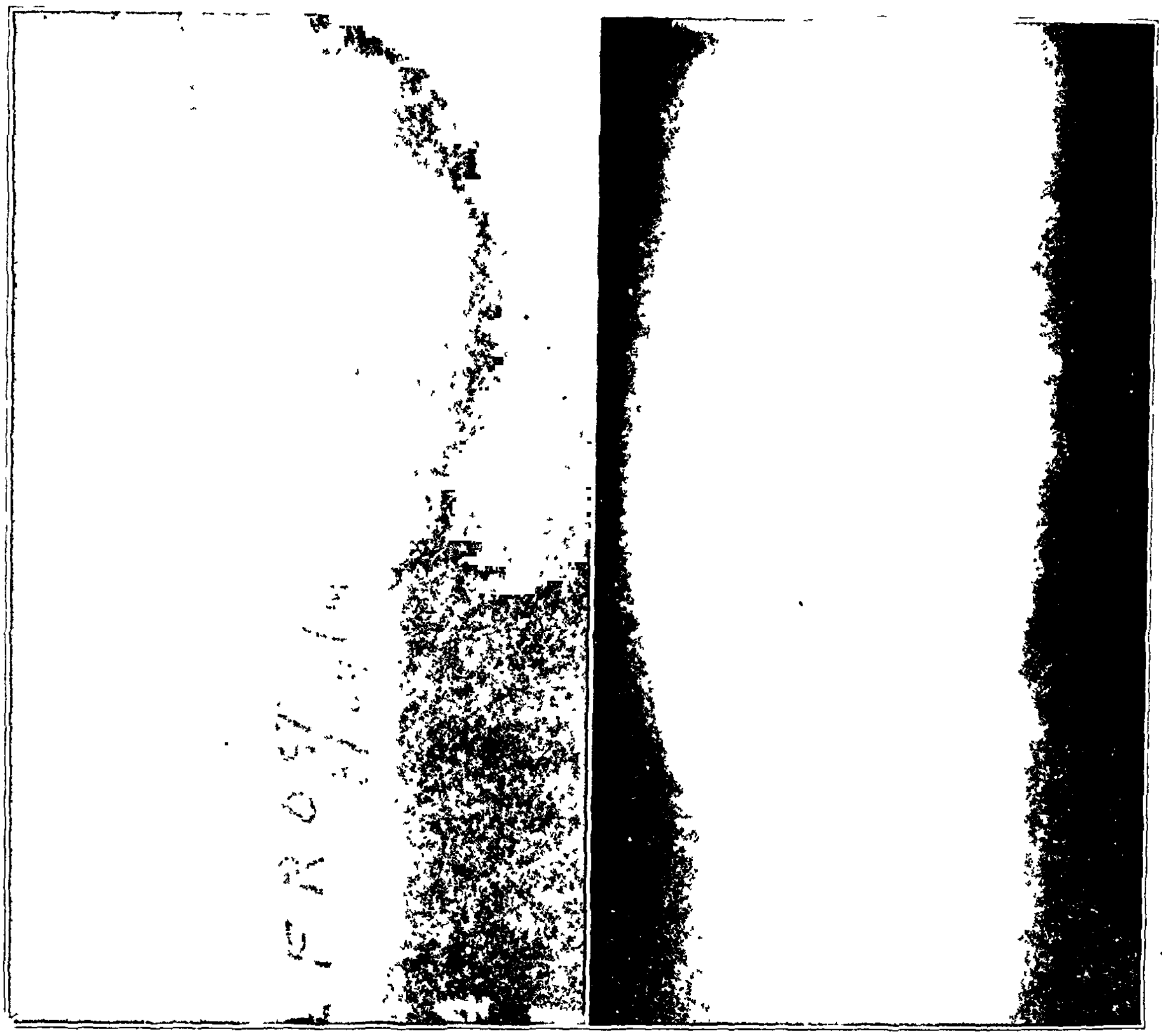


FIG. 3-A

Case 3. Anteroposterior and lateral roentgenograms show the multiple foreign bodies in the joint.

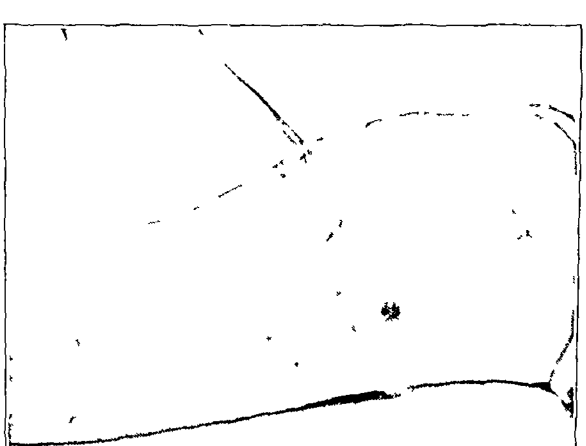


FIG. 3-B

FIG. 3-C

Fig. 3-B: Photograph of the bulging knee, before surgery on April 11, 1944.

Fig. 3-C: Several areas of damage to the articular cartilage are revealed by the medial arthrotomy incision.

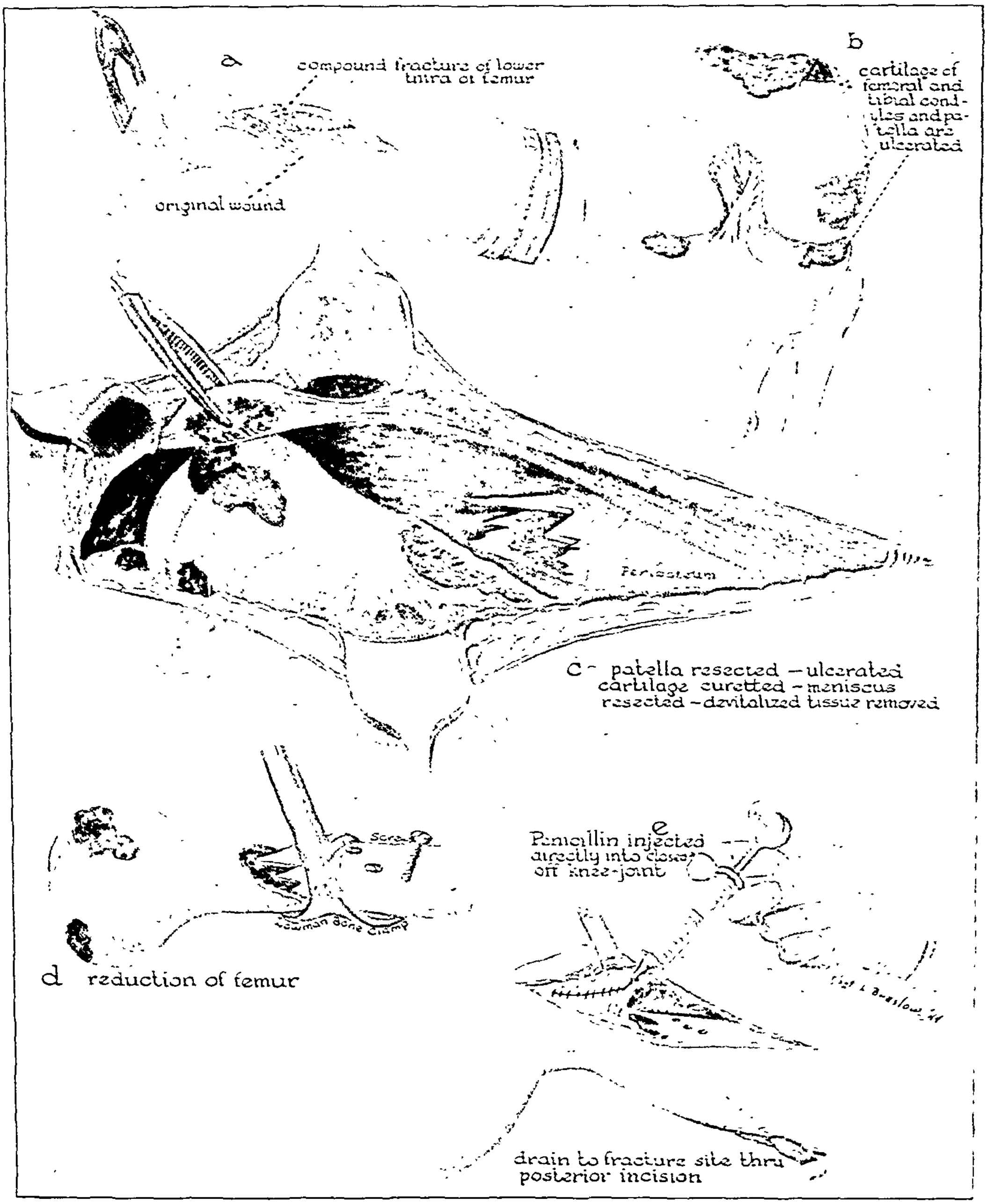


FIG. 4

Case 4. Artist's conception of the surgical procedures carried out on April 6. The extent of bone loss is not shown. (*Reproduced, by courtesy of J. B. Lippincott Company, from Annals of Surgery,* **123**: 249, Feb. 1946.)

Record at Base Hospital

Upon admission, on April 8, the patient's temperature ranged up to 101 and 102 degrees. The knee joint was painful, hot, and swollen; and pus oozed from the multiple wounds. Penicillin therapy, 25,000 units every three hours, was instituted on April 9. On April 11, thirteen days after injury, the knee was opened through a medial arthrotomy incision. The bloody pus-filled joint was irrigated. Several imbedded metallic foreign bodies were removed from the articular cartilage of the femur. The medial meniscus was friable and partially devitalized; it was therefore excised. Through a lateral arthrotomy incision, areas of devitalized articular cartilage and a friable lateral meniscus were removed. After thorough irrigation, the synovial membrane of each incision was sutured. The joint was filled with penicillin

in a strength of 1 to 1,000, and a hip spica was applied. Through a window in the cast, the synovial fluid was aspirated, and the joint was irrigated and filled with penicillin daily from April 12 to April 16, and again on April 20. At the time the wound was dressed on April 20, the joint was not swollen and the synovial membrane had healed. The temperature had reached 100 degrees each day, but settled to a peak of 99 degrees on April 23. On April 26, the wounds of the soft parts were sutured; the wounds healed. On May 8, 30 degrees of active knee motion was recorded. The patient was evacuated to the Zone of the Interior in mid-May, with a removable night splint as a precaution against flexion contracture.

Comment

The sepsis following lack of initial surgery was controlled by excision of the intra-articular foci *before* the undamaged articular cartilage was digested and destroyed. Drainage incisions probably would have been ineffective. The Theater program for early sepsis was effective, and the optimum result for the given trauma was achieved.

Fig. 5-A

Case 5. Anteroposterior and lateral views, taken on March 22, show the erosion of the medial tibial condyle and the destruction of the entire joint.

Case 4. This patient was wounded on February 20, 1944, by high-explosive shell fragments.

Diagnosis

1. Compound, comminuted fracture of the lower third of the left femur;

2. Low-grade suppurative arthritis of the left knee joint, secondary to laceration of the suprapatellar pouch and continued sepsis in a fracture of the femur.

Record at Base Hospital

On February 25, skeletal traction was instituted, with a wire in the tibial tubercle. The wounds were purulent at that time. Subsequently, several lat-

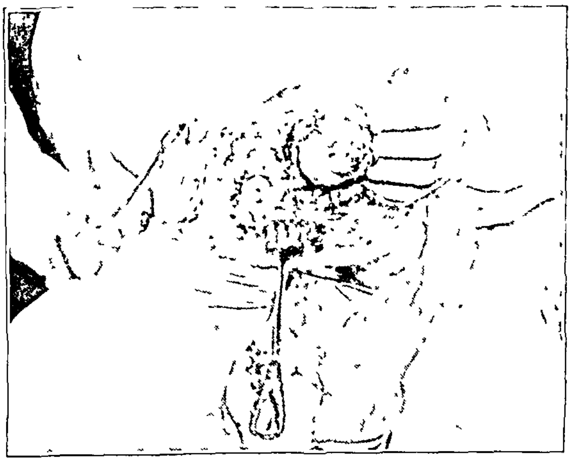


Fig. 5-B

Fig. 5-C

Fig. 5-B: Photograph of the joint, exposed at operation on March 26. The patella has been removed. For photographic demonstration, the patella is held beside the destroyed femoral condyles.

Fig. 5-C: Photograph of the resected joint. Shortening in this case was of no consequence, because of amputation of the opposite leg.

eral parapatellar incisions were made for drainage of the fracture site and the knee joint. On March 25, a pocket of pus was found in the proximal portion of the posterolateral fascial plane of the thigh. After admission, the patient's temperature had ranged between 98.6 and 104 degrees. On March 27, penicillin therapy, 25,000 units every three hours, was instituted. Blood transfusions of 1,000 cubic centimeters were given on March 28 and March 29; 500 cubic centimeters was given on March 30.

Reparative surgery was begun on March 31. At that time the posterolateral plane was incised, and the abscess and the fracture site were drained. Pus, which had tracked up the inner side of the thigh anterior to the adductor magnus, was drained by a medial incision. There was no union of the fracture. The extremity was returned to skeletal traction. A transfusion of 500 cubic centimeters of blood was given.

On April 6, through the compounding wound, the fracture was stabilized in reduction by four screws. The knee was opened by extending the incision distally. The articular cartilage of the patella was soft, eroded, and detached. There was spot erosion of the articular cartilage of the femur and tibia at points of contact, and at the place where the patella had rested upon the femur. The patella was removed. The edges of eroded cartilage were trimmed, and the bases were curetted. The joint was thoroughly irrigated, closed, and filled with penicillin The wounds of the thigh were closed, with drainage. The extremity was returned to skeletal traction. A transfusion of 500 cubic centimeters of blood was given. There was moderate discharge from all wounds of the thigh for several weeks. All reaction about the knee subsided. After two weeks, passive motion through a

Fig. 5-D
The dead infected tissue has been excised.

Fig. 5-E

Fig. 5-F

Fig. 5-E: The medial wound has been partially closed, with drainage (April 1).
Fig. 5-F: Shows closure of the lateral wound and drainage of calf abscess (April 1).

Fig. 5-G

Fig 5-H

The medial and lateral wounds have almost healed (no sinuses) on May 23.

10-degree arc was a daily routine. Only granulating areas in the old compounding wounds of the thigh remained when the patient was evacuated to the Zone of the Interior in May.

Record at Zone of the Interior

The fracture united, but it was necessary to remove two small sequestra and the screws before wound healing was achieved. Knee motion was limited to about 15 degrees. Unfortunately, in late December the patient fell and refractured his femur across the site of the bone loss. At the last report, he was still under treatment.

Comment

In the presence of abscesses tracking up the thigh on either side, an unreduced and non-uniting fracture, continuing destruction of the knee joint, and toxaemia of sepsis six weeks after the wound had been received, the prognosis was quite unfavorable. Drainage of the abscesses, excision of dead tissue in the thigh and joint, closure of the joint, reduction and stabilization of the fracture, and staged closures were followed by control of the sepsis, union of the fracture, and eventually, after removal of the sequestra and metal, by wound healing. Blood replacement and penicillin therapy were important adjuvants to the surgical treatment. The 10 or 15 degrees of joint motion which was achieved is preferable to the fusion which would have been anticipated with only drainage of the joint. The refracture in no way detracts from the achievement of the reparative surgery. It represents the hazard encountered in rehabilitation of patients with fractures of the long bones with partial loss of substance.

CASE 5. The soldier was wounded on January 8, 1944, by high-explosive shell fragments.

Diagnosis

1. Traumatic amputation of the upper third of the left thigh;
2. Compound, comminuted fracture of the medial condyle of the right tibia into the knee joint;
3. Multiple penetrating wounds;
4. Suppurative arthritis of the right knee joint.

Initial Surgery

Forty hours after injury, the traumatic amputation was completed by the guillotine method. Other wounds were debrided. Little was done to the penetrating wound compounding the fracture (almost invisible by roentgenogram) of the upper right tibia into the knee joint. The patient received 1,500 cubic centimeters of blood before and during operation.

Record at Base Hospital

After admission on January 21, the patient had continual sepsis. The amputation stump was clean, but there was profuse discharge from the upper tibia. On February 10, the knee joint was drained by bilateral parapatellar incisions. Penicillin, 25,000 units every three hours, was given intramuscularly for two weeks. Repeated blood transfusions were given. Sepsis continued, with fever up to 102 degrees. On March 3, roentgenograms disclosed total destruction of the medial tibial condyle. On March 9, a large abscess on the lateral aspect of the thigh, but connected with the knee joint, was incised. On March 12, systemic penicillin therapy was re-instituted. On March 23, the patient appeared quite ill, and amputation was considered as a life-saving measure. His temperature reached 102 and 103 degrees daily. Blood therapy in the Base Hospital totaled 4,500 cubic centimeters. On March 24 and 25, an additional 1,500 cubic centimeters was given.

At operation, on March 26, the old incisions on either side of the patella were extended proximally to drain abscesses of the thigh. Another abscess in the calf was incised. Lateral reflection of the patella disclosed that the joint cartilage, including that of the patella, had been totally destroyed by sepsis. The destroyed bone was resected, and the patella was removed. The bones were held in approximation by an anterior wire loop. The old wound edges were excised, but closure was not done. A hip spica provided immobilization. A transfusion of 1,000 cubic centimeters of blood was given during the operation, and 500 cubic centimeters was given on March 27 and again on March 28. The only temperature rise above 100 degrees during the first five days after operation occurred following a mild transfusion reaction. On April 1, the spica was removed in the operating room; the old blood clot was irrigated away; and the wounds were partially closed, with drains to the back of the old joint space and to the calf abscess. The blood given on this day totalled 1,500 cubic centimeters. On April 7, the abscess in the calf required further incision. On that day 500 cubic centimeters of blood was given. All drains were omitted, and the wounds were dressed with dry fine-meshed gauze. The wounds granulated to produce almost complete healing, and the knee fused to stability. The patient's temperature remained at 99 degrees or under.

Penicillin was discontinued on April 20. An interesting observation was that, in spite of the subsidence of his sepsis, the blood transfusions, and an increased appetite, the patient definitely appeared to lose weight,—a phenomenon attributed to the mobilization of abnormally retained interstitial fluid. Later he

Fig. 6-A

Fig 6-B

Fig. 6-A: Case 6. The knee is ready for surgery (April 24).

Fig. 6-B: The destroyed joint has been exposed. The possibility of restoring joint function was hopeless

Fig 6-C: Photograph of the resected articular surfaces of the femur and tibia. Note the destruction of articular cartilage.

Fig. 6-D Lateral and anteroposterior roentgenograms of the resected knee

Fig 6-C

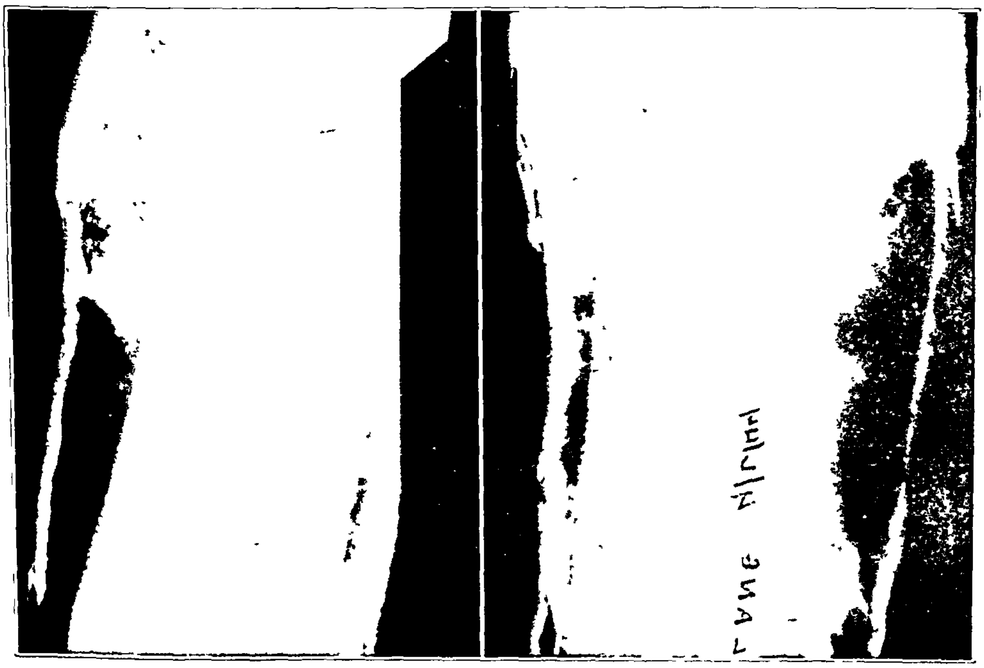


Fig. 6-D

gained weight and appeared well. He received a total of 12,500 cubic centimeters of blood over a three-month period. In late April, he was transferred to a Canadian hospital, and since then follow-up information has not been available.

Comment

The ravages and potential dire consequences of knee-joint sepsis, the ineffectiveness of drainage incisions, particularly after septic destruction of articular cartilage, and salvage of a limb and possibly of a life by resection of the knee, are illustrated in this case.

CASE 6. This patient was wounded on April 3, 1944, by high-explosive shell fragments.

Diagnosis

1. Perforating wounds of the right knee joint;
2. Compound, comminuted fractures of the right femur, supracondylar and condylar, the right patella, and the right fifth metatarsal;
3. Laceration of the patellar tendon;
4. Early suppurative arthritis of the knee joint, superimposed on severe trauma.

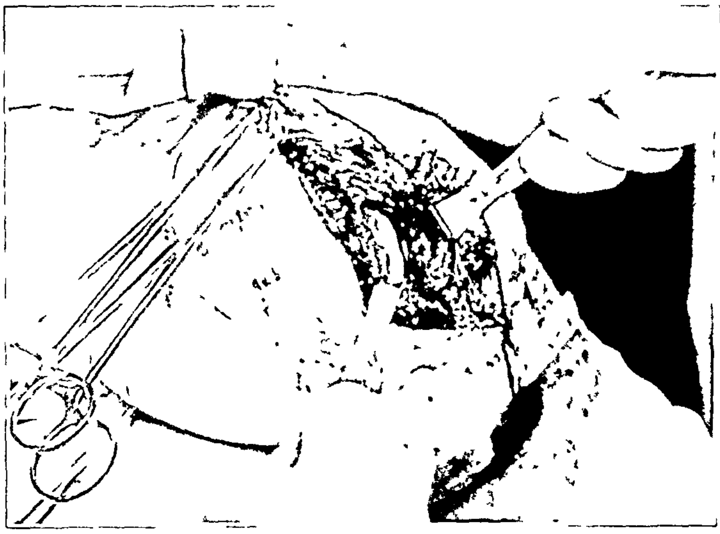


FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 8. Photograph of the interior of the knee at the time of operation (July 14). The edge of the damage to the articular cartilage is visible. Note the intense hyperaemia.

Fig. 7-B: On August 7, the operative wound had healed and the joint was normal in size.

FIG. 7-C

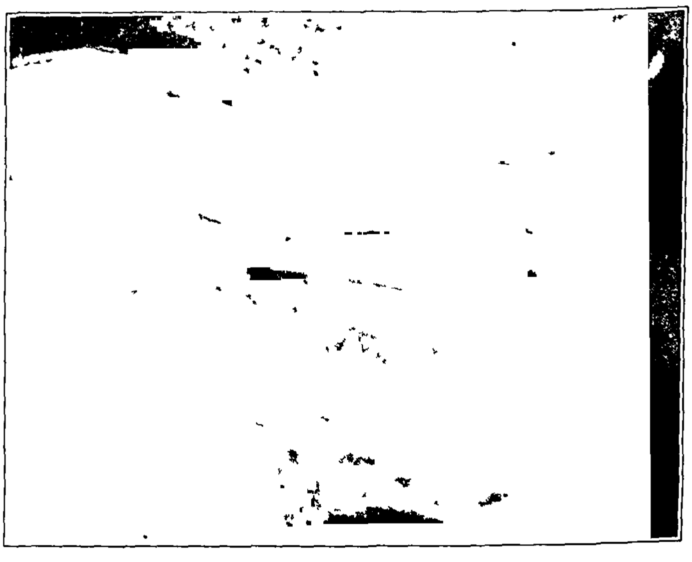


FIG. 7-D

Fig. 7-C: Reproduction of anteroposterior roentgenogram, taken early in 1945. The extent of condylar damage is demonstrated.

Fig. 7-D: Shows the range of knee motion in 1945. Complete extension was possible, but is not shown here.

Initial Surgery

Following excisional surgery, which included removal of the comminuted patella, wire sutures were used to approximate the patella and the quadriceps tendons, and the skin flap over the knee was held in place by two silk sutures. A Steinmann pin was passed through the distal condylar fragments, presumably in an effort to avoid spread or rotation of the condyles. (The use of skeletal fixation in forward areas is not recommended.) The pin emerged through the wounds, medially and laterally.

Record at Base Hospital

The patient was admitted on April 14. The joint and the fracture site were bathed in pus. An effort was made to obtain reduction of the supracondylar fracture by joining the previously placed Steinmann pin to half-pins inserted in the femoral shaft by the apparatus of external skeletal fixation. Reduction was not achieved. Between the time of admission and April 23, the patient's temperature ranged up to 102 degrees. Systemic penicillin therapy, 25,000 units every three hours, was instituted on April 19. Between April 19 and April 23, the patient received 4,600 cubic centimeters of blood.

On April 24, three weeks after injury, in the operating room, it was determined that pus was oozing about the pin and from the knee joint. The pin was removed. Through a lateral incision, the supracondylar fracture was stabilized in reduction by two screws and a wire loop, in spite of some bone loss. Examination of the knee disclosed a hopelessly destroyed joint. The sutures previously placed in the skin flap and the patellar tendon were removed, and the articular surfaces of the femur and tibia were resected. The flap of skin was sutured in place so as to cover all exposed bone. Rubber drains emerged from the back of the joint, through posteromedial and posterolateral wounds. Half-pins were inserted in the tibia, and connected to the half-pins in the femur by the rods used in external skeletal fixation; fair fixation of the knee in good apposition was thereby achieved. A single hip spica was applied, which incorporated the apparatus. A transfusion of 1,000 cubic centimeters of blood was given during the operation. On May 3, through a sleeve resection of the cast, the drains were removed and the remaining wounds were prepared for a staged closure by excising the skin edges and the old granulation tissue. The external skeletal fixation was quite advantageous in maintaining stability during the surgical procedure. On May 8, a bit of protruding external condyle was chiseled away, and the wounds were sutured. Wound healing was achieved, except for a persistent sinus from the region of the supracondylar fracture. The patient was evacuated to the Zone of the Interior late in July.

Record at Zone of the Interior

The patient was seen by the Surgical Consultant of this Theater in January 1945; at that time there was firm fusion and wound healing, except for the sinus, which was recognized as reaching a sequestrum in the old internally fixed fracture.

Comment

The badly damaged extremity, with early sepsis, presented a problem in wound management. Obviously, full function could not be restored. The damage to the joint precluded hope for future motion of the knee. The internal fixation maintained length, stabilized the fracture, and permitted the knee-joint surgery. Removal of the avascular, necrotic tissue (the keystone of reparative surgery) obviated the hazard of sepsis and permitted procedures to achieve wound healing. Although an arthrodesis was performed, the objective of the operation was the control of sepsis, with wound healing,—not arthrodesis. The optimum result for this severe injury was achieved in a minimum period of time by application of the principles of reparative surgery.

CASE 7.* The patient was wounded about October 15, 1944, by multiple high-explosive shell fragments.

Diagnosis

1. A severe avulsing wound of the right knee;
2. Compound, comminuted fractures of the left humerus, radius, and tibia, and of the right femur (not considered here);
3. Paralysis of all nerve trunks of the left arm (not considered here).

Initial Surgery

The right knee joint and the lines of fracture of the femur, extending into the joint, were exposed because of an avulsion of the patella and expansion of the outer side of the quadriceps. Following thorough cleansing of the joint, a graft of fascia lata was utilized immediately to achieve a closed joint, and penicillin was instilled.

* The surgeon performing the initial surgery was Major Small of the Fifty-Sixth Evacuation Hospital.

Record at Base Hospital

This record was not available.

Record at Zone of the Interior

The patient was observed in March 1945, with a small unhealed granulating area over the old wound of the knee joint. The joint was freely movable through a range of 30 degrees.

Comment

The excellent initial surgery was the important factor in the salvage of the knee joint. Had the joint remained open, it probably would have been destroyed by sepsis and necrosis of the exposed cartilage.

CASE 8. The patient was wounded on July 1, 1944, by high-explosive shell fragments.

Diagnosis

1. Penetrating wounds of the left knee joint, arm, ankle region, and shoulder;
2. Early suppurative arthritis of the left knee joint.

Initial Surgery

Seven hours after injury, the knee joint was opened and a foreign body, embedded in the medial femoral condyle, was removed. The joint capsule was sutured. Penicillin was instilled into the joint; and systemic penicillin therapy, 25,000 units every three hours, was instituted. The patient was evacuated in a split toe-to-groin plaster cast.

Record at Base Hospital

The patient was admitted on July 6. The daily temperature range was from 98 to 101.4 degrees. The knee was painful and swollen, and pus was oozing from it. The joint was irrigated through a large needle, and 20 cubic centimeters of penicillin, in a strength of 1 to 1,000, was instilled on two occasions. On July 13, the patient's temperature was 101 degrees, and the knee was swollen, boggy, and tender. A seropurulent discharge leaked from the joint. Maggots crawled from the wound.

On July 14, the joint was opened through the old wound, plus a proximal extension. Maggots again were present. A piece of woolen cloth and, from beneath it, a devitalized area of articular cartilage about one inch in diameter, depressed into a defect in the condyle, were removed. The defect was trimmed evenly and the joint was thoroughly inspected for further damage, but none was found. The medial meniscus was dull in appearance, but it was not friable and so it was not removed. After thorough irrigation, the synovial membrane and the capsule were closed, and the joint was filled with penicillin. Immobilization was achieved by means of a Tobruk splint. A dirty wound of the ankle was debrided, but was not closed. Wounds of the shoulder were excised and sutured, with drainage. Systemic penicillin was continued. On the second and third days after operation, the synovial fluid was aspirated, and the joint was irrigated and filled with penicillin through a large needle. The temperature remained under 100 degrees for five days, and then under 99 degrees. On July 19, five days later, the skin was sutured; this left a gap in the center (because of tension) and also a raw area over the patella. Quadriceps exercises were instituted. Penicillin therapy was discontinued on July 29. On August 7, the wound was almost healed. Daily periods of knee motion, active and passive, were instituted. On August 22, it was noted that the joint reaction had subsided, quadriceps power was present, but only 10 to 15 degrees of flexion could be obtained. The shoulder wounds had healed. The patient was evacuated to the Zone of the Interior in September, with removable splinting for use at night as a precaution against flexion contracture.

Record at Zone of the Interior

On April 5, 1945, the patient was observed by a representative of this Theater at a Convalescent Hospital. All his wounds had healed, and knee motion was possible from extension to 100 degrees. The knee was reasonably stable, and the patient had no complaints other than his restricted motion.

Comment

This case illustrates the necessity for and the effectiveness of an aggressive surgical program in early knee-joint sepsis. Obviously, drainage alone would not have controlled the sepsis, or have prevented complete destruction of the joint. The excisional surgery was the most important factor in the achievement of the excellent result. With the pabulum for joint sepsis removed, and with penicillin therapy to protect living tissue from invasive infection, the remainder of the program was effective in avoiding recontamination, obtaining healed wounds, and promoting the early resumption of function. In the presence of inadequate initial surgery, penicillin therapy *did not prevent sepsis.*

CONCLUSIONS

1. At the time of the initial surgical treatment, the preferred plan of management for penetrating wounds of the knee joint—regardless of the time interval between receiving the wound and operation—should include arthrotomy; excision of the devitalized tissue, including areas of destroyed articular cartilage; cleansing of the blood clot and debris from the joint; suture of the synovial membrane or capsule; and immobilization of the limb in a hip spica or a Tobruk splint.

2. At the time of reparative surgery, preferably from five to ten days after the intra-articular surgery, the skin should be sutured.

3. Immobilization should be discontinued as soon as the danger of sepsis is past and the skin has healed, or is healing. Active and passive mobilization should then be instituted.

4. In cases of suppurative arthritis of the knee joint, potential or established, the same surgical plan is indicated.

5. Continuous drainage of fluid from the knee joint is not adequate surgical treatment in cases of suppurative arthritis; moreover, it is not indicated.

6. Systemic penicillin (at present the best available antibacterial agent), supplemented by the local instillation of penicillin into the joint, should be employed in patients with wounds and suppurative arthritis of the knee joint, in order to prevent invasive infection of the living tissue.

7. In the light of the problem and the hazards of knee-joint sepsis, knee-joint resection has a definite, but fortunately a limited, application in the management of severe wounds and sepsis of the knee joint in military surgery.

NOTE: This program was developed under the supervision of Colonel Edward D. Churchill, Surgical Consultant, Mediterranean Theater of Operations, United States Army; and in conjunction with Major Champ Lyons, of the Theater Consulting Staff, and Colonel Howard E. Snyder, Surgical Consultant, Fifth Army. The majority of the patients seen during the formative phase of the program were on the services of Major Joe M. Parker and Captain John J. Modlin, Twenty-First General Hospital; Majors Joseph Godfrey and Benjamin E. Obletz, Twenty-Third General Hospital; and Lieutenant Colonel George Duncan and Major R. D. Butterworth, Forty-Fifth General Hospital.

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SKIN-GRAFTING IN THE TREATMENT OF OSTEOMYELITIC WAR WOUNDS *

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During the past three years the writer has witnessed at close range the application of skin-grafting techniques to the healing and subsequent treatment of osteomyelitic wounds.[6,7] There is little basic difference between closure by skin grafts, either free or pedicled, and secondary or primary closure, as advocated and developed by Key, Dickson and his associates, Churchill, and Hampton during the War and the years which immediately preceded it. In some war wounds, loss of both bone and soft tissue is so extensive as to preclude secondary closure, and some other means must be sought for inducing prompt healing. Free skin grafts will often effect healing of such wounds.

At Ashford General Hospital this work has been carried out on an Orthopaedic Section manned by officers whose training has been in orthopaedic surgery, general surgery, or a combination of the two. A concerted effort has been made to satisfy the principles of skin transference, with especial reference to the avoidance of tension and the development and protection of the blood supply in pedicle grafts. In some instances the technique which could be applied to the task was inadequate to meet such basic requirements in the circumstances which arose. Obviously, these instances represent failures. These failures are in some measure offset by the prompt, good results obtained in the predominating group of successes, and by appreciation of the severe problems presented by some cases. Because of his tremendous backlog of battle casualties, the skill of the army plastic surgeon will not be available to many patients with osteomyelitis for several years. The orthopaedic surgeon, with an understanding of the basic principles of skin transference, but usually with little training in its details, will have to face some of these problems. It is the writer's intent to present an abstract of the experience of the group with which he has been associated in this work.

SAUCERIZATION

Saucerization is a traditional word. Like débridement, it fails to describe accurately what is performed, but will probably continue in use for lack of a better term. Not only all dead tissue, but also all devitalized tissue must be removed, and the contour of the wound must be such that subsequent application of appropriate pressure to a skin graft will be possible.

FREE SKIN-GRAFTING

After saucerization, if the wound does not admit of tensionless closure with suitable elimination of dead space, skin-grafting is needed. Occasionally a pedicle skin graft may be applied directly to a well-saucerized wound. More often, a free graft must be employed, although usually this is but a temporary measure. Application of a free skin graft is an excellent test of the adequacy of the saucerization, for, wherever necrosis exists in the bed, there one encounters failure of "take".

Optimum Time for Grafting: A number of skin grafts have been performed at the same time as saucerization. Others have been done as much as six weeks afterward. At present, the author prefers the interval of four days. Following saucerization, vital tissues

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

within the wound assume a coat of granulations. Necrotic tissues and those of low vitality fail to do so, and will not sustain a skin graft. An appraisal of the receptiveness of the wound to a free skin graft is based purely on its gross appearance. Under an appropriate pressure dressing, the granulations developing in a period of less than four days will be

FIG. 1-A

Result in severe arm wound with osteomyelitis of humerus, distraction, delayed union, and radial palsy.

Fig. 1-A: Appearance six weeks after being wounded by high-explosive shell fragment. Note necrotic bone in upper portion.

Fig. 1-B: Shows wound five days later, after saucerization and pressure dressing. Note generally healthy appearance; radial nerve is seen in anterior third of wound.

FIG. 1-B

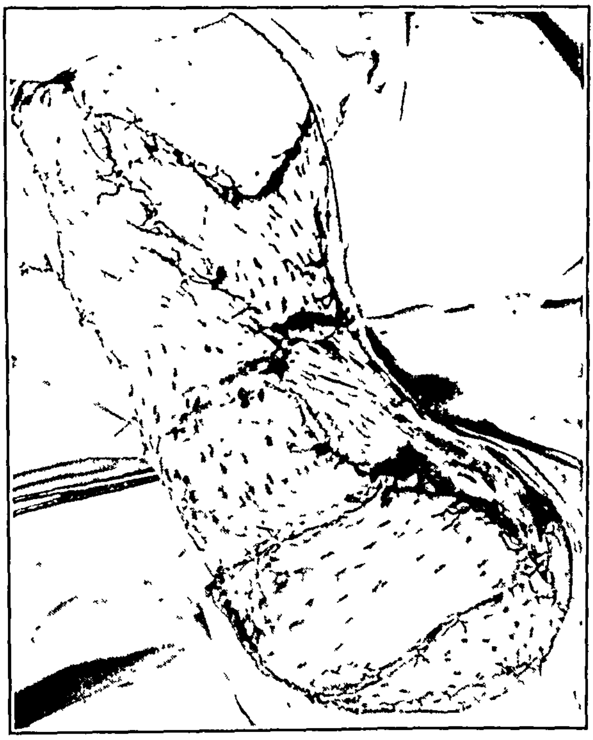

FIG. 1-C

Fig. 1-C: Skin graft has been sutured into place. Note close fit of graft to contours of wound.

FIG. 1-D

Fig. 1-D: Late result. Early "take" was better than 95 per cent.

FIG. 1-E FIG 1-F FIG 1-G

Serial roentgenograms show spontaneous union Function returned to radial nerve in this patient.

too inconspicuous to permit of ready differentiation between vital tissue and that which is necrotic, or potentially so. When such tissue is found in the wound, further surgery is performed for its eradication, and a new pressure dressing is applied. This procedure is repeated until, upon removal of the dressing, one finds only healthy tissue. No attention is paid to the bacterial flora present. Other technical factors being equal, results have appeared to be proportionate to the health of the bed into which the graft was applied.

Thickness of Graft: Certain situations justify the hope that a successful free skin graft will afford stable coverage of the wound [7], and that subsequent treatment will be unnecessary. A graft 0.016 inch in thickness is probably ideal. A large number of grafts have been of this thickness, and the "take" has been excellent. Based on a few cases at Ashford General Hospital and on a number of Knight's cases, which the author has had the privilege of observing, it seems apparent that thin grafts make for more rapid stabilization of healing. Knight, believing that all free grafts should be replaced, favors thin ones.[9] Considerable slough is apt to develop when thicker grafts are used. Separation of this slough requires time and care during the postoperative interval. Once this process is complete, an excellent coverage is present, a large percentage of whose surface contains skin accessories. Lessened surface necrosis attendant upon the use of a thin graft leads to more rapid completion of secondary epithelization; it saves time and trouble, and helps the patient's morale.

PEDICLE GRAFTS APPLIED TO SAUCERIZED WOUNDS

Immediate application of pedicle grafts to saucerized wounds is feasible when saucerization has been thoroughly carried out and no potential dead space exists. Except for the abdominal variety, pedicle skin grafts can seldom be made available without advance planning. One is rarely able to predict in advance what the skin requirements will be after saucerization. Therefore, only in the upper extremity, and in but a few instances, has

Fig. 2-A

Fig. 2-B

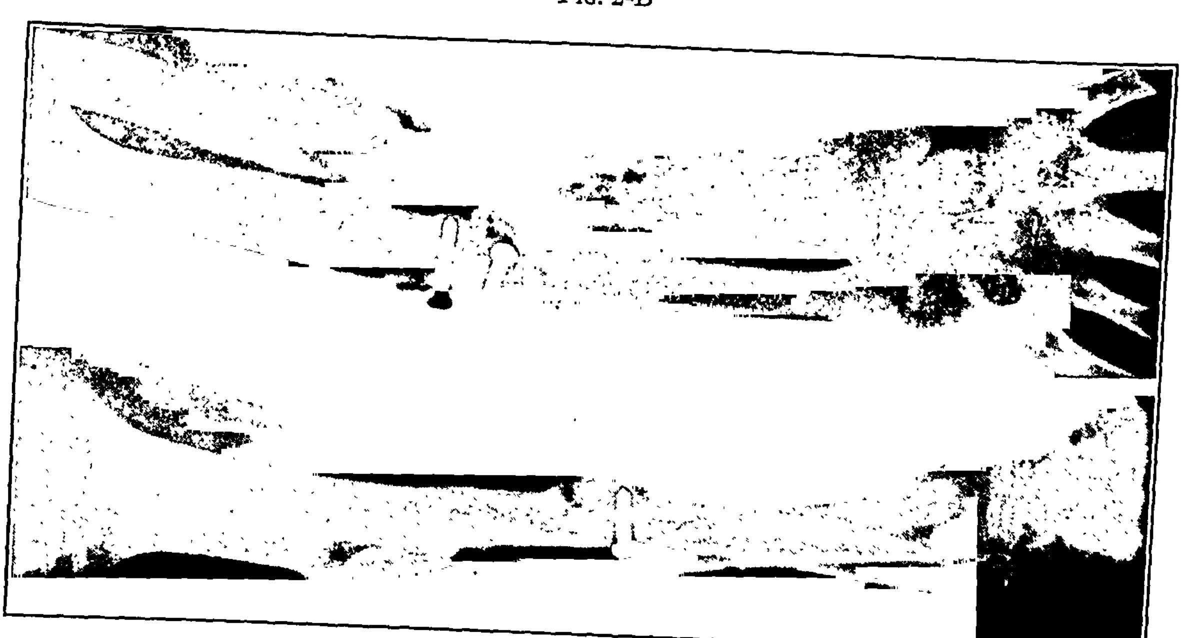

Fig. 2-C

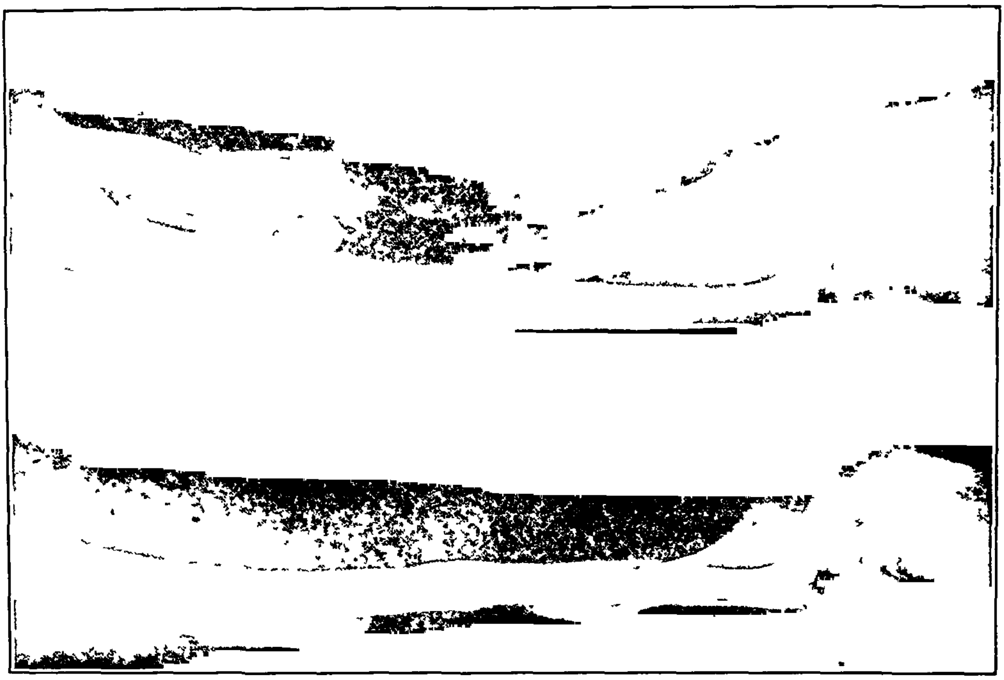

FIG 2-D

Wound treated by saucerization and early application of abdominal pedicle flap, by-passing dermatome graft.

Fig 2-A. Photograph of original wound

Fig 2-B Saucerized wound four weeks later, immediately prior to application of abdominal pedicle.

Fig 2-C Roentgenograms taken just before saucerization.

Fig 2-D Roentgenograms two months after application of pedicle

Fig 2-E Roentgenograms taken after bone-grafting

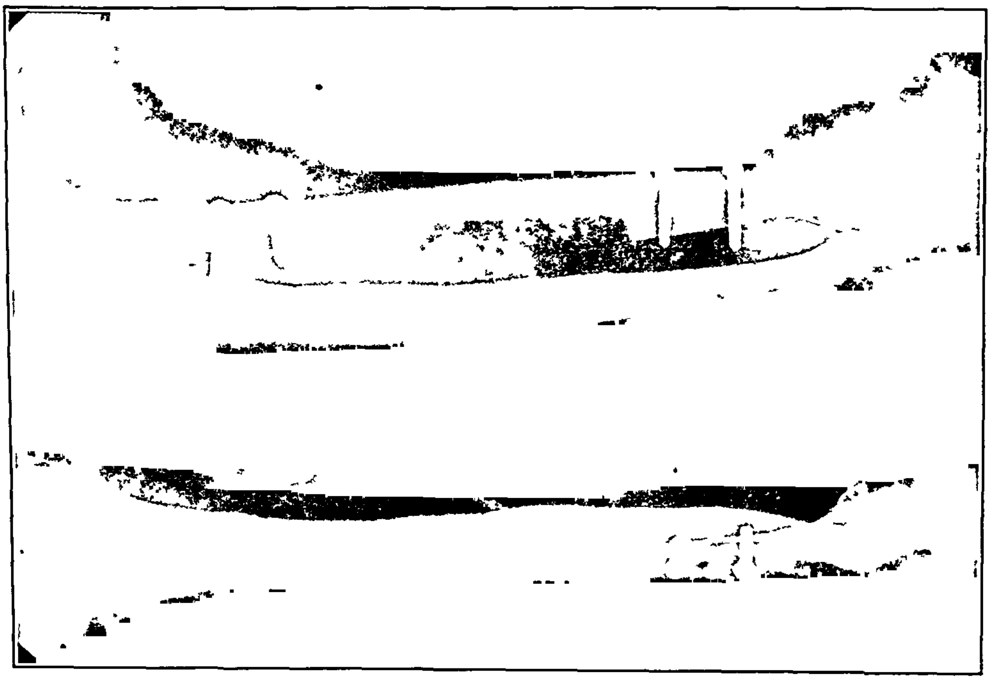

FIG 2-E

the free graft been by-passed. Moreover, in the humerus presenting osteomyelitis with well-established non-union, healing of the fracture frequently follows saucerization, free skin-grafting, and immobilization (Figs. 1-A to 1-G). Thus we are left mainly with the forearm, upon which to practise direct application of the pedicle graft to the saucerized wound (Figs. 2-A to 2-E).

REPLACEMENT OF FREE GRAFTS

If replacement of a graft is anticipated, it is well to plan it at the time of saucerization. When a free skin graft is applied, the first stage in the development of any pedicle which is needed may be carried out. In some instances induration and oedema, persisting long after saucerization, preclude secondary closure. As surface healing progresses in response to free skin-grafting, however, local tissues become more pliable, and closure is practicable. After excision of the free skin graft, simple closure may be effected by approximation of opposing tissues, or it may be necessary to form some type of pedicle from local tissue.

Abdominal Pedicle Flaps: Abdominal pedicle flaps, as described by Brown, have been most satisfactory to repair skin defects of the arm and forearm (Fig. 3). If the pedicle is relatively wide, the flap can be based in any direction. At first a preliminary elevation was performed, and a free skin graft was placed beneath the flap a week before its initial application. Portions of these free grafts were lost through maceration and friction, and we now realize that most defects left in abdominal skin by transference of flaps can be closed by undermining and approximating the skin edges. Larger and more complicated flaps should be planned in advance. A stockinette pattern may be cut the shape of the area to be covered, although a little larger. The pattern, cut with a wide pedicle, may then be strapped to the abdomen with adhesive tape in various positions (Figs. 4-A to 4-E). Thus one can assure in advance an abundant blood supply at the base, a comfortable and readily maintained position of the arm during transfer of the flap, and a pedicle free of abrupt kinks or twists. The pattern may be sterilized with the instruments for use at operation.

FIG. 3

Representative abdominal pedicle flap. Note extreme width of pedicle, absence of abrupt twisting, kinking, or torsion, and comfortable position of forearm.

The wider the base with respect to length of the flap, the safer. The limit of safety for a flap, to be raised and applied in one stage, is in the ratio of two units of length to one unit of width of pedicle base. Where the base includes the epigastric vessels, this ratio can safely be exceeded somewhat. It is a good rule to proceed slowly, watching for the danger sign of cyanosis of the skin edges. If this is encountered before the flap is completely elevated, a delay of a week will be necessary. A corollary to this is that one should not denude the area to be resurfaced until a transferable flap has been assured.

Adhesive strapping serves as a satisfactory immobilizing agent for most abdominal pedicle flaps. It should be applied so as to discourage maceration and permit frequent dressings.

Cross-Leg Pedicles: The technique outlined by Ghormley and Lipscomb in performing cross-leg pedicles has been followed. Advance planning is again important, and may be carried out as explained previously. A preliminary outlining down to the deep fascia is

made by parallel incisions, a nearly complete undermining is done a week later, and a dermatome graft is placed beneath the pedicle at the end of the second week. With the use of the dermatome graft, "takes" have been excellent; and there have been no deleterious effects on the deep surface of the overlying pedicle. True, there has been fibrosis of this deep surface, which is resected when the flap is applied; but such a procedure seems necessary with any flap undermined at a stage prior to its application, and the necessity of performing it cannot be blamed solely on the dermatome graft. It is of considerable advantage to have the donor site already surfaced with skin at the time the pedicle is transferred. The end of the flap to be transferred is partially severed a week after dermatome grafting, and a few days later it is completely severed and initially applied to the recipient area.

To avoid abrupt kinking and twisting of the pedicle, it is sometimes desirable to outline the flap obliquely, or even to base it distally instead of proximally The farther the axis of the pedicle deviates from the normal direction of blood flow in the extremity, the greater the care with which it must be developed If the base or direction of a cross-leg flap, prior to the initial application, is bizarre, partial severance had best be carried out in two or more stages

FIG 4-A FIG 4-B

FIG 4-C FIG 4-D

FIG 4-E

Planning and execution of a large abdominal pedicle flap
Defect (Fig 4-A) and stockinette pattern held in place with adhesive tape (Fig 4-B)
Pattern in position on arm (Fig 4-C) and flap similarly placed (Fig 4-D)
Fig 4-E Result

Just before initially applying the cross-leg pedicle, the legs are placed in the intended position of application, and the position of the joints is noted. Plaster immobilization is applied to each leg individually, in order to maintain fixation in the position noted. Ample windows expose the pedicle and the area for resurfacing. After transfer of the pedicle to its new site, which is effected through stockinette draping over the plaster, one has but to join the two plasters by incorporating braces, making sure that no tension exists on the

Fig. 5-A

Fig. 5-B

FIG. 5-C

Fig. 5-A: Pedicle of fat from large tube used to fill cavity. Note size of tube.

Fig. 5-B: Large pedicle of fat developed from tube, which is perhaps a little long for safety. Note tibial cavity with gauze sponge in its depth

Fig. 5-C: Fat pedicle being led into cavity.

Fig. 5-D: Application of tube to wound. Because of the excessive length of its pedicle, the fat became necrotic after the final stage.

FIG. 5-D

pedicle. Whenever possible, a pedicle skin graft should be observed for circulatory changes in two hours, and again in twenty-four hours, after application. Minor adjustments may avert disaster; and, at times, immediate return of the pedicle to its previous site may be indicated because of poor circulation.

DEAD SPACE

The replacement of dermatome grafts, originally applied to saucerized osteomyelitic wounds by the process described, is practicable, provided the contours of the skin-grafted area present no potential dead space. All such space must be obliterated if one hopes successfully to effect replacement of the dermatome graft by pedicle skin transplants. Localized pressure or localized tension sutures, used in

an attempt to force the pedicle into dead space, jeopardize the circulation to distal points of the pedicle. To avoid this, one must eliminate cavities by some means which do not offer insufferable insult to tissues.

Autogenous Iliac-Bone Chips

The author has had dismal failure in attempting to introduce chips into bone cavities in these wounds; infection resulted in most cases. Knight and Wood have reported success. No explanation can be offered for these failures; iliac chips have been employed with success in less favorable circumstances. Other means have thus been sought for dealing with cavitation.

Tubed Pedicles

One alternative to iliac-bone chips for filling these cavities is fat brought in with a tubed pedicle of skin. The fat can be "inverted" into the cavity in various ways (Figs. 5-A to 5-D), care being taken to maintain its blood supply intact. Where the cavity is excessively large and steep, a tremendous tube may be required, and here this method finds its greatest limitation.

Although the two-to-one ratio of length to width may be slightly exceeded in most tubes with safety, there is little to be gained from it in these patients. Later extension of the pedicle, either by a "paddle" or by further tubing of skin, is more feasible. After two weeks, the end of the tube for transference is pinched off for increasingly long periods, up to a half hour, with minimum color change indicating good circulation.

Most of the trouble with tubes has arisen from shortcomings in that sphere with which orthopaedic surgeons should be most familiar,—namely, immobilization. When tubes are transferred, the suture line must be protected from tension and excess mobility, and the entire tube from kinking. During transfer to the wrist, a plaster body jacket fixing the shoulders and hips has been found most satisfactory. This is joined by braces to a plaster, which maintains the wrist in cock-up position and the elbow flexed as much as the position of the tube permits. The angle of approach of the tube to the wrist, which can be controlled at this stage, should be planned so as to minimize kinking at the next stage; and forethought results in placing the eventual position of the suture line so that the tube need not be subjected to torsion, when transferred. The window in the arm plaster, through which the tube passes to its suture line at the wrist, must be ample to avoid impingement on the tube. For the same reason, the extremity must be fixed firmly in the plaster by dorsiflexing the hand and flexing the forearm. These principles of immobilization should be adapted to successive stages of transplantation of the tube, and rigidly observed.

Methyl Methacrylate

Captain E. R. Zaglio, of the Orthopaedic Section at Ashford General Hospital, has recently used implants of methyl methacrylate as a filler of dead space in the wounds under discussion. Several patients have been treated in this fashion. Skin to cover the acrylic has been taken from practically every source mentioned in the foregoing discussion, and prompt healing has resulted in each instance. It seems reasonable to hope for success in replacing these implants with bone after a time; likewise that in certain instances this rather inert substance may be left in place indefinitely.

SUMMARY AND CONCLUSIONS

Techniques of plastic surgery can be applied to the treatment of certain types of osteomyelitic wounds. Success in producing healing by free skin-grafting has been considerable. Later stages of reconstruction in these instances have succeeded, often in proportion to the operator's facility in performing pedicle skin transplants. In replacing free

skin grafts with pedicles in this group of patients, dead space presents a major problem. Contrary to the experience of others, attempts at Ashford General Hospital to fill such cavities with iliac-bone chips have resulted in a high proportion of infection; and other filling materials have been used, with varied success.

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DISCUSSION

Colonel Leonard T. Peterson, *Medical Corps, Army of the United States*: My experience with the technique described by Colonel Kelly has been limited to observation of the orthopaedic surgery at a considerable number of Army hospitals. In the early months of the War, it was customary to treat chronic osteomyelitis for long periods with plaster and infrequent dressings. Often the surgeon was reluctant to carry out the surgery required for adequate drainage and removal of sequestra. I am glad to say that a more aggressive attitude has been taken in recent months, with the excision of sequestra and other devitalized tissue, followed by early skin-grafting. Secondary closure of these wounds, without preliminary skin-grafting, has not usually been successful. The development of early saucerization, followed by skin-grafting, parallels closely the early secondary closure of compound wounds, as developed especially in the Mediterranean Theater and later practised in all theaters.

The method presented today represents one of the most important developments in reconstructive surgery of the War. Colonel Kelly deserves praise for his careful and honest evaluation of his results. Colonel Knight has recently published his outstanding results in bone-grafting the large defects which remain after skin-grafting. The orthopaedic and surgical consultants have contributed toward encouraging improved methods.

RESTORATION OF BONE STRENGTH WITH REINFORCEMENT BONE GRAFTS *

BY LIEUTENANT COLONEL GEORGE K. CARPENTER, MAJOR ROBERT T. ROSENFELD, AND MAJOR KARL F. MECH

Medical Corps, Army of the United States

Frequently a fracture progresses to union of such limited extent that full function should not be permitted because of the danger of refracture. This condition of bone healing occurs most frequently after severe compound, comminuted fractures of the long bones, particularly if there is an associated loss of bone substance. The authors have called this status of insufficient fracture healing by the descriptive term of "limited union". It has been found possible to restore bone strength and substance by the application of autogenous bone grafts, thus reinforcing the site of limited union sufficiently to permit earlier and unprotected use of the extremity.

The condition called limited union is not to be confused with delayed union. Delayed union progresses to solid bony union in due time, and the end result is compatible with normal function. Limited union is actually a condition of solid bony union; but the end result is a shaft which is incapable of normal function, since it is weaker and usually smaller than normal. The protected use of the extremity, such as with the prolonged use of a brace, does not, as a rule, stimulate increased bone substance at a sufficiently rapid rate to justify such a conservative procedure.

Limited union may manifest itself in various ways. The fracture may be united by bridging callus, with no evidence of union between the fragments. A comminuted fragment may bridge a large bone defect and solid bony union may result, but the fragment cannot possibly increase sufficiently in size and strength to permit unprotected use of the extremity. Another type of limited union is seen frequently following the loss of a large comminuted fragment which does not include the whole circumference of the shaft, and in these cases the shaft is rendered smaller in size at the site of union. Since severely compound, comminuted fractures often become infected subsequently, healing occasionally results in sclerotic bone which is not so strong as normal bone. Limited union is also seen occasionally after simple fractures.

There is no claim to originality in the reinforcement of the site of limited union by bone grafts for the purpose of quickly strengthening the fracture site sufficiently to permit normal function. One of the writers (G.K.C.) employed such a procedure as long as twenty years ago; but it was not until World War II that the operation was done in large numbers or without having first used a walking brace for many months in the vain hope that a larger and stronger fracture repair would develop. In the early days of this War we were inclined to delay; and, in so doing, many valuable days were lost. A few patients on furlough were sent to Halloran General Hospital following refracture, and roentgenograms often showed that the fracture had occurred at the site of limited union. Refracture occurred in two of the authors' patients while they were in the Hospital, in spite of awareness of this problem and vigilance in protecting the extremity. A compound, comminuted fracture is likely to require a long period of treatment, and early recognition and grafting in cases of limited union will very materially lessen the length of time necessary to effect recovery. All patients showing by roentgenogram the early manifestations of limited union are possible candidates for a reinforcement graft. It has always been the authors' policy to delay a bone-graft operation until three months after complete wound healing, in order to minimize the incidence of infection. The extent of bone healing at this time will nearly always

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22, 1946.

indicate whether the fracture will progress to a complete and sufficient union by conservative measures.

The first operation performed at Halloran General Hospital for limited union took place on November 26, 1943.

On March 30, 1943, the patient had sustained a severely compounded, comminuted fracture in the upper third of the shaft of the right femur. He was admitted to the Hospital on April 30. The plaster

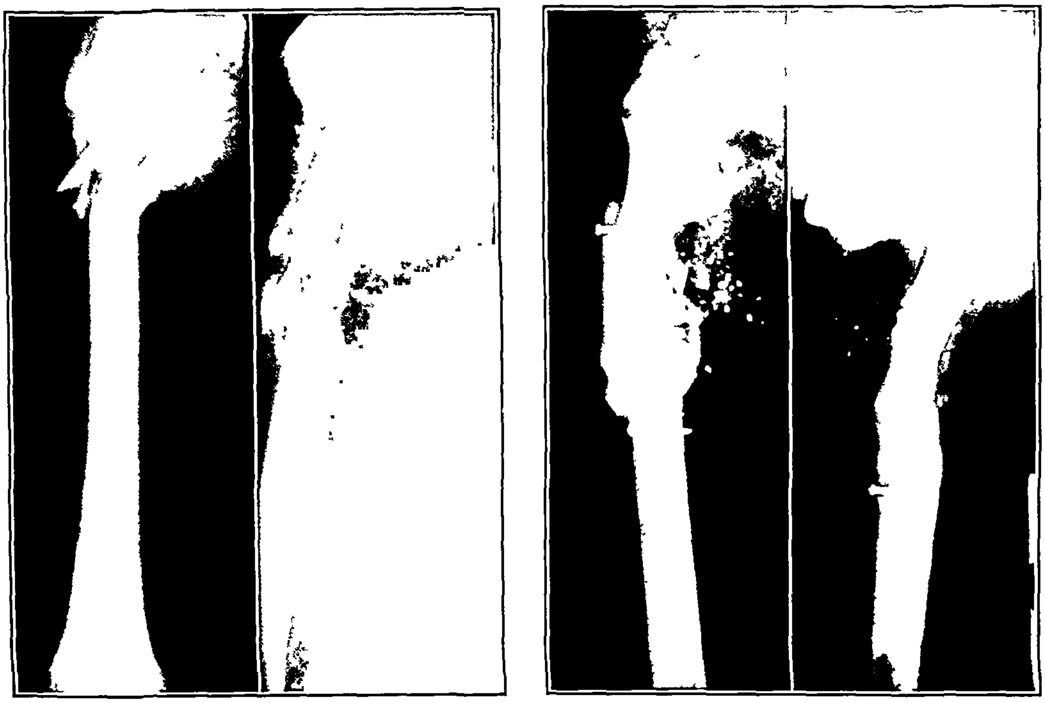

Fig. 1-A Fig. 1-B

Fig. 1-A: Case 1. Limited union of femur, six months after injury.
Fig. 1-B: End result after operation.

Fig. 2-A Fig. 2-B

Fig. 2-A: Case 3. Severe compound, comminuted fracture of the femur, with limited union.
Fig. 2-B: Result after bone-grafting for limited union.

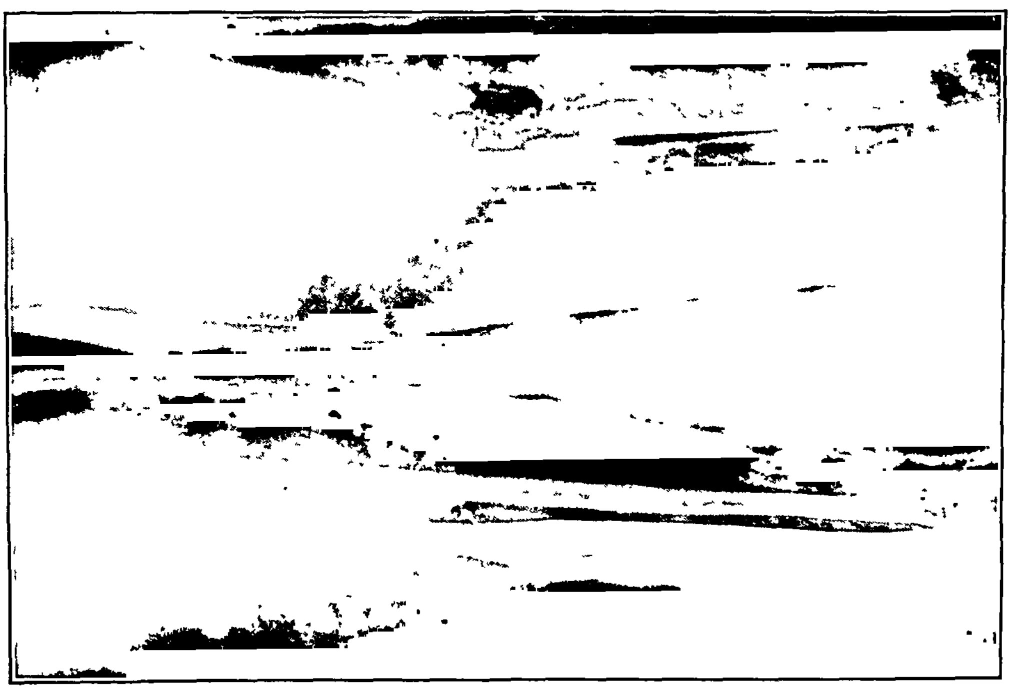

FIG. 3-A

Case 6. Severe compound, comminuted fracture of tibia, prior to sequestrectomy.

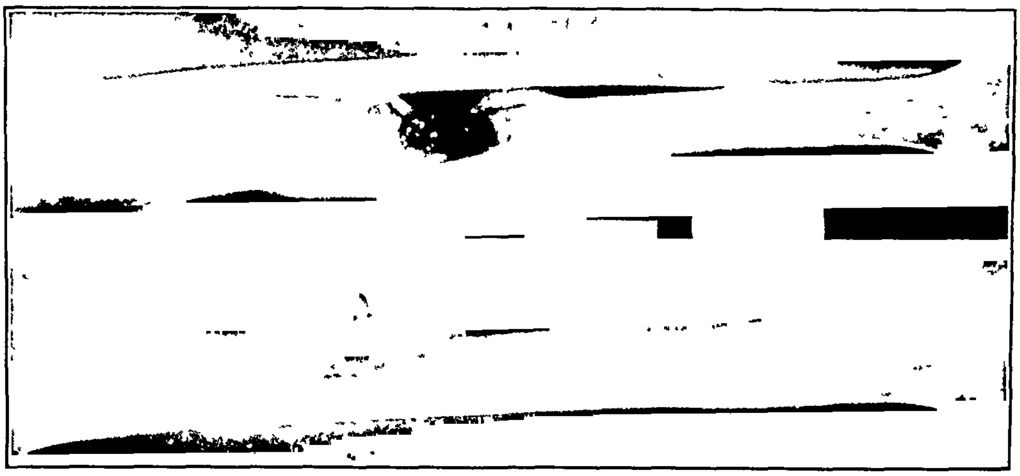

FIG. 3-B

After sequestrectomy, showing limited union.

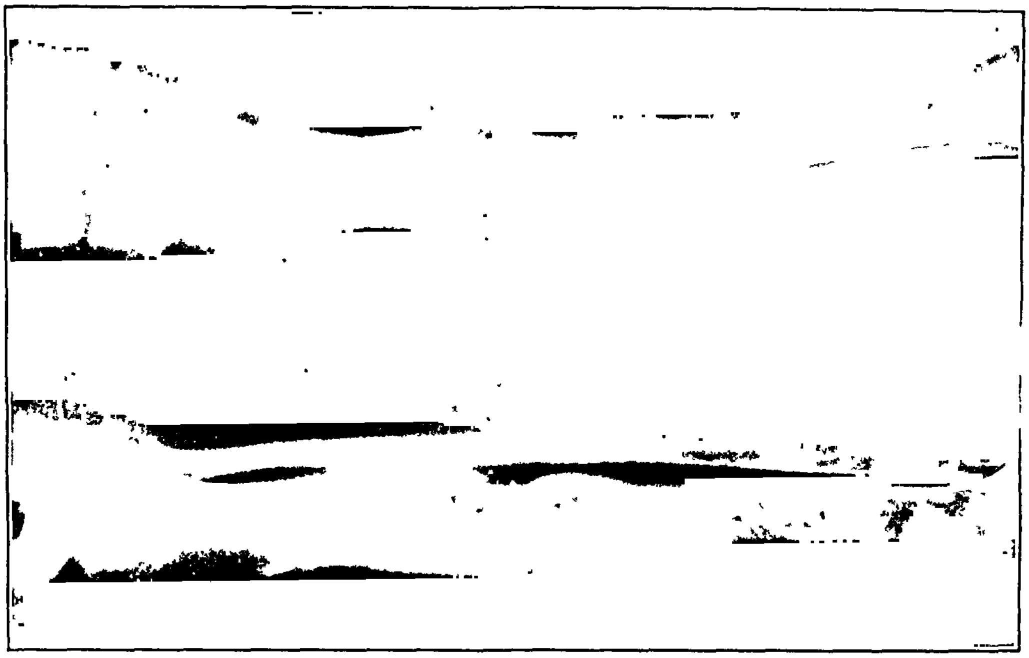

FIG. 3-C

Three months after bone-graft operation.

cast, which had been applied in Africa, was immediately removed, and the limb was put in suspension-traction. The patient had also sustained a compound fracture of the left radius. Both wounds healed promptly. Clinical and roentgenographic examinations made four months after the injury showed bony union, but the roentgenograms revealed so much loss of substance at the fracture site that it was believed necessary to continue the use of traction. After four months of traction, the roentgenographic findings were unaltered, and a reinforcement bone-graft operation was performed. This patient could have been operated upon three months earlier, as wound healing had occurred in less than two months after the

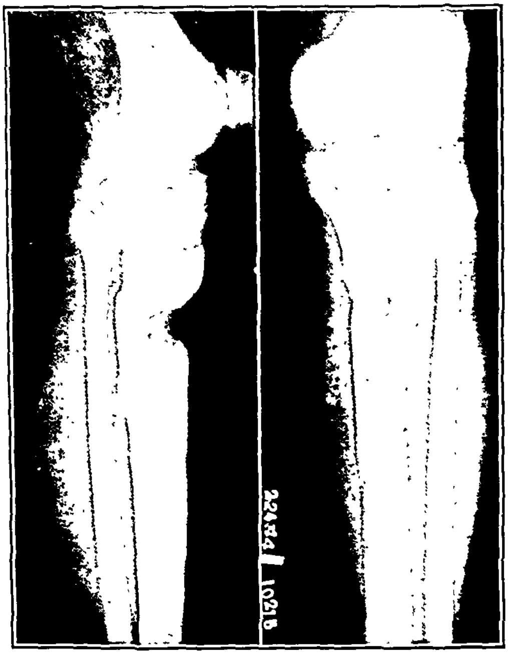

Fig. 4-A

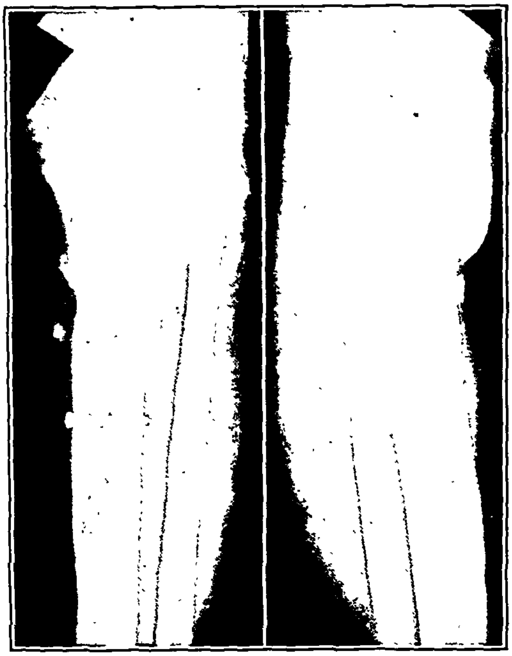

Fig. 4-B

Fig. 4-A: Case 7. Showing defect of tibia; limited union is present. Prior to bone-graft operation, the scar tissue was removed from the bone defect, and the cavity was obliterated and covered with a full-thickness skin graft.

Fig. 4-B: End result, following bone-graft operation.

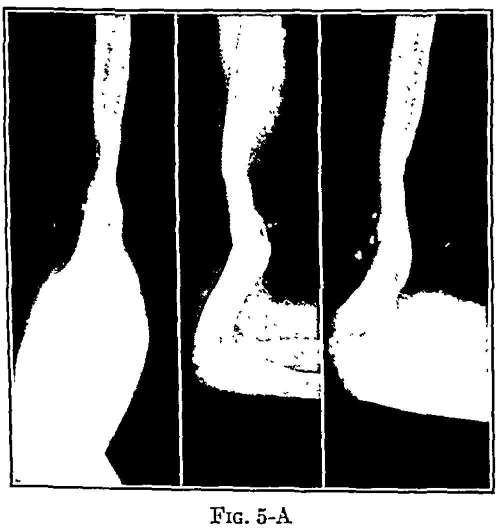

Fig. 5-A

Fig. 5-B

Fig. 5-A: Case 9. Showing limited union of humerus, following a severe compound, comminuted fracture which became infected. Notice dense sclerotic bone.

Fig. 5-B: Anteroposterior and lateral views, after bone graft. Note that osteotomy was not performed to improve the mild angulation at the site of fracture.

injury, and he had suffered very little infection. Limited union was not recognized early, and, in consequence, the operation was performed at the end of eight months. The end result, however, was as follows: no deformity, no shortening, no limitation of joint motion, and, finally, excellent function. This patient remained in traction for more than ten months, but fortunately he was confined in plaster for only the first month after injury.

Well-supervised physical therapy, which included an effective exercise program to preserve muscle tone and joint motion, did much to hasten the restoration of function in this and similar cases.

From November 1943 to September 1945, a total of fifty-two operations for limited union were performed at this Hospital by reinforcement bone grafts. The bones requiring operation were as follows: femur, nineteen cases; tibia, eleven cases; first metatarsal, one case; humerus, eleven cases; ulna, six cases; and radius, four cases. These operations were performed by the various members of the Orthopaedic Section; the writers either performed or assisted in the majority of the operations. Tibial grafts with multiple chips and cancellous bone from the upper tibia were used in most cases. Iliac grafts may be used advantageously. Since in these cases union is present, even though it is not strong, it is unnecessary to employ extensive internal fixation of the graft, nor is external splinting always necessary. The extent of the limited union will help to determine the character of the fixation of the tibial graft and the type of external splinting. As a general rule, screws are used to fix the graft; and plaster casts are used for external fixation, except for the femur, which is almost always treated postoperatively in suspension-traction.

No new operative methods are presented, as it is believed that any type of sound grafting will be effective. Naturally, a sufficient amount of bone must be used to effect strong bony union. Penicillin therapy has been used, both before and after the bone-graft operation. The prerequisites for bone-graft surgery, which have been recorded by the authors and by such other writers as Brown, Lyons, and Murray, demand meticulous preoperative and postoperative care, both of the patient and of the involved extremity. When the patient and the extremity have been properly prepared for bone-graft surgery, the incidence of complications will be very low and excellent operative end results will be obtained. In one patient a previous infection flared up, but it was controlled quickly; and the case progressed to good bony union after removal of the screws and a small portion of

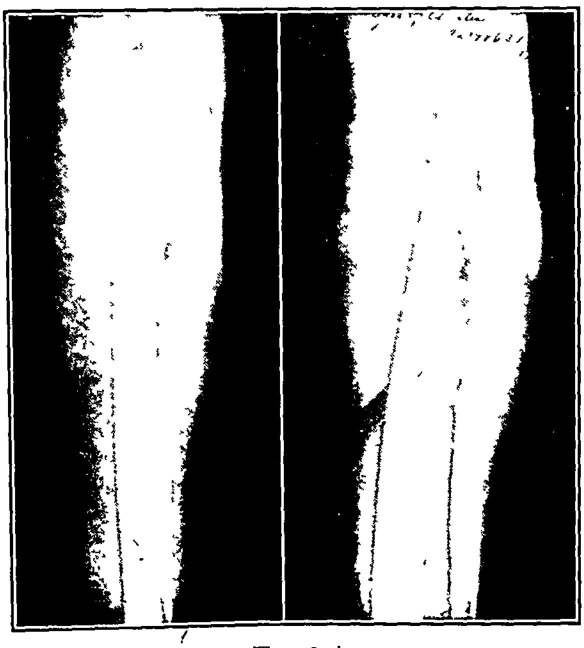

Fig. 6-A

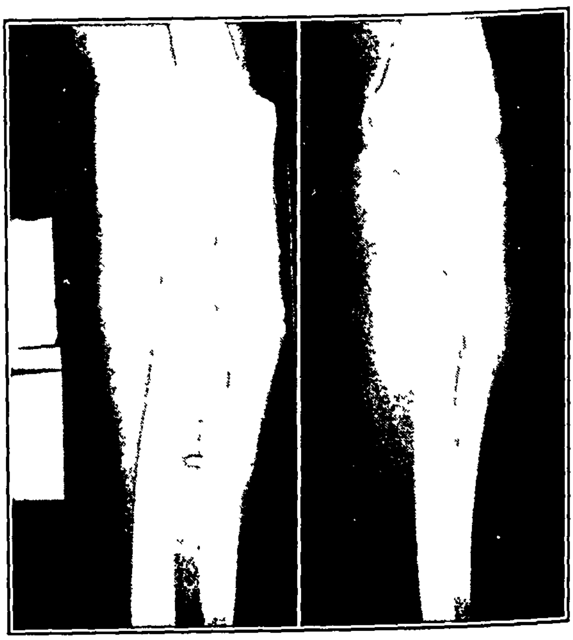

Fig. 6-B

Fig. 6-A: Case 13. Roentgenograms show limited union of ulna.
Fig. 6-B: Roentgenograms show final end result after bone-graft operation.

the graft, which had sequestrated. It has been possible in all instances to restore bone size and strength sufficiently to permit unprotected function following reinforcement bone-graft operations for cases of limited union.

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DISCUSSION

Dr. W. W. Plummer, Buffalo, New York: As Civilian Consultant to the Orthopaedic Sections of the General Hospitals of the Second Service Command, it has been my privilege during the past two and one-half years to make frequent visits to Halloran General Hospital. As a result of those visits, I have had the opportunity of reviewing personally much of the material presented by Dr. Carpenter. Some of these cases I have seen through to the stage of end results. I would like to say that, under the conditions described in the speaker's presentation, the procedure has my wholehearted approval. I am sure, from what I have seen, that a protracted recovery period has been materially shortened, and a functional end result has been obtained, compatible with the type of original injury and superior to the end results expected from our previous experience with similar cases.

My personal observation of the cases upon which this presentation is based has led me to make two comments. The first is that, watching the progressive changes noted in a series of roentgenograms throughout the recovery period of any one of these cases, it seems to me that the bone graft itself and the adjacent bone structures show a remarkably rapid vascularization and trabeculation, and increased bone bulk. My own opinion is that, where there is solid union, the osteogenetic activities of the graft material are hastened.

My second comment refers to this same problem, in relation to the ununited fractures of the shafts of long bones. In 1932, at Toronto, I presented some twenty-odd cases of non-union of fractures of the shafts of long bones. Those cases were in a way analogous to the material under discussion, because all the patients had been through a series of one or more reconstruction procedures. All the fractures had failed to unite, and some of them had been complicated by infection. All of the cases of that series were treated by internal fixation (plating) plus osteogenetic material of some sort,—onlay, inlay, or chip grafts, or osteoperiosteal ribbon, as the individual case seemed to demand. My thinking at that time was based on a maximum amount of positive fixation with a minimum amount of surgical trauma. Thus I favored the plates and bone grafts, as against single or multiple massive grafts, which required extensive soft-tissue stripping to permit application of enough bone-graft material to supply adequate fixation. This produced minimum disturbance of existing blood supply in an already extensively traumatized area. In all of those cases the fractures progressed to functional union.

The point I am trying to make is that, in the light of the material so ably presented in the paper under discussion, we might well consider the desirability of the addition of internal fixation by an inert metal, with the expectation of more rapid healing and a consequent shortening of the recovery period, in our civilian cases of ununited fractures.

Colonel Robert H. Kennedy, *Medical Corps, Army of the United States*: As Consultant Surgeon, Second Service Command, I have had the opportunity of observing many of the patients at Halloran General Hospital upon whom the essayists performed these reinforcement bone grafts. The importance of the subject is far too little recognized. In fact, it would appear that many surgeons have never heard of it.

The possible later application of this procedure is one of the excellent arguments for maintaining proper length and axis, even in the presence of a large bone defect. On several occasions at Halloran I have seen perfect length and axis with a bridge less than a quarter inch in diameter across a wide defect. A reinforcement graft is not so formidable a procedure for this patient as is a graft for a complete defect. Less exposure and manipulation are required to prepare the bed; complete internal fixation is obtained with less hardware; and a much shorter period of immobilization after operation is required. Constant supervision of proper traction in the large defect is as important as in any other case.

It has not been uncommon to see patients, sent to the Convalescent Hospitals for reconditioning from General Hospitals all over the country, with union so limited that it is hard to imagine why the bones have not refractured long before, after the braces were removed. Apparently the surgeon has been so pleased to get bony union that he has forgotten that, if union exists in one half the diameter in each of two right angle planes, it means that a 25 per cent. volume of bone is called upon to do the work of 100 per cent. This is mature bone or sclerotic bone, and in either instance it will increase in diameter but little, since it is already surrounded largely by scar tissue. The time to have reached the decision that more bone would be required was within three months after wound healing; further delay in most instances entails useless confinement for the patient. Refracture means starting over again, with a poorer chance than the first time.

If the original strut has any strength before the reinforcement graft is applied, the time of external immobilization or traction can be markedly diminished afterward. Many patients will need no more than two or three weeks,—that is, until good wound healing has been obtained. If this volume of bone was sufficient to permit the patient to walk before operation, there will be no particular strain at the site of an onlay graft; and after a few weeks even the position of chips will change but little. This fact overcomes one's hesitation to immobilize the joints a second time for a prolonged period. The main requirement, however, is to give the patient a sufficient amount of strong bone to support him safely the rest of his life,—not merely until he is out of the surgeon's hands.

THE SURGICAL PRINCIPLES OF SPLIT-THICKNESS-SKIN GRAFTING

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INTRODUCTION

Plastic repair of lost integument does not lie in the domain of the plastic surgeon alone, but also comes within the sphere of the orthopaedic surgeon. Little is gained by restoring the continuity of a bone and preserving the integrity of a joint, if deformity and loss of functional activity result from scar tissue.

There is no doubt that early replacement of skin loss decreases mortality, morbidity, and the cost of illness, and prevents disfiguring scars, deformity, loss of function, and the occurrence of unsuitable weight-bearing surfaces.

John Staige Davis, in discussing a paper[24] read before the American Surgical Association in Chicago, May 3, 1944, stated: "It has been my observation over many years, that skin grafting, although a fairly simple process in the hands of those who know how and when to use it, is more consistently bungled than almost any other surgical procedure."

Although the author claims no originality for the methods advocated, and recognizes that this paper does not deal exhaustively with the many problems confronting the surgeon who contemplates restoration of lost integument, he will attempt to present those factors which have given him the most satisfactory results and which he believes to be basic surgical principles in the rational treatment of those cases which can be treated by split-thickness grafts. Skin-grafting requires infinite attention to multitudinous details of technique, the utmost gentleness. and intimate understanding of wound-healing processes. It should not be a fortuitous occurrence, since its success can be assured by an understanding of the surgical principles involved.

Contributions advocating new techniques have been so numerous in the medical literature in recent years that the casual operator is frequently bewildered as to the method to be used. This contribution was conceived with the view of presenting sound surgical principles for the basis of indications for the split-thickness graft.

HISTORY

The practice of tissue transplantation dates back to antiquity. The East Indians and Egyptians performed rhinoplastics 3,000 years before the Christian Era by the use of a pedunculated flap from the forehead.

Although Tagliacozzi at the University of Bologna, in 1597, is credited with founding the Italian school of rhinoplasty, by his own writings he concedes that his method of repair was based upon the teachings of Branca, a Sicilian surgeon of the year 1442. Following Tagliacozzi's death, plastic surgery fell into disrepute because of the influence of the church; and very little progress was made until the Nineteenth Century.

With the ebb and flow of civilization and learning, Carpue, a London surgeon, revived the Indian flap method of transplantation in the year 1816. Concurrently, Dieffenbach in Germany started transplantation experiments in animals. Although fickle history has placed the mantle of recognition about the shoulders of Jacques Louis Reverdin, a Swiss of French ancestry, as the first to transplant a small piece of skin in 1869, Dieffenbach was the first to succeed, in 1824. Similarly, although Louis Xavier Ollier contributed a paper in 1872 on the successful transplantation of a sheet of thin skin and Carl Thiersch's first paper on a similar result appeared in 1874, yet it was George Lawson of London who reported the first successful attempt on November 11, 1870.

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John Reisberg Wolfe published the first paper on full-thickness grafts in 1875, and a few years later Fedor Krause reported on over 100 successful full-thickness grafts.

The full flood of the advance of plastic surgery was reached at the turn of the century. Goldmann, in 1893, and John Staige Davis and Traut made notable contributions to our understanding of the mechanism by which grafts "take". Davis introduced the deep pinch graft, which was a decided improvement over the Reverdin graft; although its application in modern skin transplantations is very limited in scope, it still has a place in the treatment of skin loss in debilitated patients and in those whose wounds are grossly infected and thus offer little chance for the survival of more suitable types of replacement.

The disadvantages of using this medium for skin replacements are that the donor site is almost always spoiled as a donor area for other types of graft; the donor and recipient areas are unsightly; and the result is functionally unsuitable because of the massive scar tissue between the pinch grafts.

The author heartily agrees with the statement of Gabarro, when he says: "Many reasons are given to explain why the pinch graft takes so easily. In my opinion, the main reason is that the grafts are so placed that enough room is left between them to allow of free discharge, and nothing intervenes between the graft and the recipient area." The use of the pinch graft has, therefore, resulted in applying emphasis to an important surgical principle. In infected or potentially infected wounds, adequate measures must be taken in the application of other forms of skin transplantation to assure free drainage for the successful take of the graft. This will be elaborated upon later.

Many varieties of pinch grafts have been described. They include the chessboard graft of Gabarro, Poth's strip grafts, cut to form "flagstones", the sieve grafts of Douglas, and postage-stamp grafts. A long glossary of names may be compiled to designate variants of the multiple small grafts. The one feature which differentiates these grafts from the Reverdin and Davis grafts is that a sheet of split-thickness skin is cut, either free hand or by mechanical means, thus assuring regeneration of the donor site. The graft is then cut into various shapes and sizes and placed upon the recipient bed. Many methods of maintaining contact between these small pieces of skin and the bed have been described. Among them are the coagulation contact method and the pliofilm-covered multiple grafts of Hardy and McNichol. Other variants of multiple small grafts may be mentioned, including Braun's method of burying small pieces of living skin in the depths of the granulating tissue in heavily infected areas, and the tunnel grafts described in 1912 by MacLennan and in 1917 by Esser. All these methods have limited usefulness in special cases; they are not methods of choice, but of necessity.

The scrape and injection method[1,10] of skin-grafting is mentioned here merely to condemn it as unsurgical in principle and unsatisfactory in results. In no case thus far reported has healing taken place before the lapse of many months of treatment, and the end result was unsatisfactory functionally and cosmetically. Infinitely more adequate methods are known, based upon sound surgical principles of preoperative care of the recipient area and resurfacing of the wound.

Credit for the full-thickness graft rightly belongs to Blair, John Staige Davis, Garlock, Dragstedt, and Conway. Filatoff in 1916 and Sir Harold Gillies in 1917 introduced the tubed-flap graft.

Padgett introduced the dermatome, which placed in the hands of surgeons an instrument that makes the cutting of a graft a matter of mechanical precision. To Blair, Brown, McDowell, and Padgett go the credit for the introduction and popularization of the split-thickness graft.

Recent literature is replete with references to new techniques in the use of free grafts. Some are based upon sound scientific principles and will endure; and others will disappear into oblivion.

THE SPLIT-THICKNESS GRAFT

The split-thickness graft has the greatest range of usefulness in the repair of skin loss of all methods of skin transplantation. Three types are to be distinguished: first, the thin split-thickness graft, or Ollier-Thiersch graft; second, the intermediate split-thickness graft of Blair; and third, the thick split-thickness graft. These differ from one another only in the amounts of epidermis and dermis which are taken. At one time it was believed that the Thiersch graft represented merely the epidermal elements of the skin; but all authorities agree that it is somewhat more substantial than that, and includes at least parts of the papillae of the skin. Its thickness is usually between 0.006 and 0.01 inch. The intermediate split-thickness graft of Blair varies from 0.012 to 0.016 inch. The thick split-thickness graft is from 0.02 to 0.024 inch; it may represent from two-thirds to four-fifths of all the skin elements present. The intermediate and split-thickness grafts have in a large measure displaced other forms of skin transplantation, except in special cases. They do not have the disadvantages of a Thiersch graft, which is inadequate functionally and cosmetically. The Thiersch graft, although useful and successful as a temporary coverage to obtain healing in moderately infected areas, is unsuitable for weight-bearing surfaces and areas exposed to trauma; and its property of contraction makes it unsuitable for use over joints or mobile surfaces. The full-thickness graft is also rapidly being replaced in large measure by the use of the thick split-thickness graft, except in cases of syndactylism or Dupuytren's contracture, and in small areas. A split-thickness graft of from 0.02 to 0.024 inch has almost all the advantages of a full-thickness graft, without the risk of loss. In the hands of the most expert operator, partial or total failure of full-thickness grafts occurs in 20 per cent. of cases in the aseptic wounds; in the granulating wounds the percentage of take is so small that it does not warrant the risk.

A split-thickness graft or any free graft will not "take" on exposed tendons or bare cortical bone without periosteum; but if the area is small—for instance, less than one centimeter—it may carry a lateral blood supply of its own to bridge small areas. The split-thickness graft takes well on fat, muscle, granulation tissue, and even on scar tissue. Furthermore, a split-thickness graft causes no concern about coverage of the donor area, as rapid regeneration in this area from sweat glands and hair-follicle elements is assured. Brown and McDowell[4] have referred to this as "dedifferentiation" of the deep glands of the derma into squamous epithelium, and state that the squamous epithelium covers the surface in from six to eight days.

The thickness of whole skin varies greatly according to age, sex, race, complexion, various degrees of nutrition, and different areas of the body. The character of the skin varies also in different portions of the body. In children, the skin rarely exceeds 0 016 inch in thickness. In adult males, the skin is thicker than in females; in fair-complexioned people it is thinner than in dark-skinned individuals. The skin from the chest, abdomen, inner aspect of the upper arm, or inner thigh is thinner than that on the back, outer thigh, or buttocks.

On the back the epithelium is relatively thin, but the derma is so thick that a full-thickness graft from this area cannot be relied upon to survive. This region, however, is useful as a donor area for repeated grafts. Brown and McDowell[3] report taking five crops of split-thickness skin from this area; in one instance, only nineteen days elapsed between the taking of two successive grafts. The skin on the palms and on the soles of the feet is the antithesis of that on their dorsal aspects; the epithelium is thick, the derma is thin, and hair follicles are not present.

Homografts take almost universally, even without regard to blood groups. Brown and McDowell report their use in twenty-six patients who were grouped by the M and N classification. Although these homografts may be life-saving and are frequently used in children with extensive burns, they begin to disappear in three weeks by a melting-away

process without pus formation, and are completely absorbed in from ten to eleven weeks. It appears that the proteins of homografts are antigenic and that the host requires about three weeks to build up a maximum allergic response, as evidenced by the fact that application of a second homograft from the same donor fails completely. As an emergency measure, it stops pain; there is improvement of the patient's general condition; and the graft appears to stimulate the wound to epithelialization. Brown, in 1937, reported one instance of successful homografting in identical twins.

Skin preserved by refrigeration usually fails to take, although isolated cases of success have been reported with skin preserved up to two weeks. In the author's opinion, it is useless to tempt fate with so uncertain a procedure.

Split-thickness grafts can be used in the following situations: (1) in clean granulating surfaces; (2) over the yellow base left by excision of granulation tissue; (3) in extensive burns, crushing injuries, or avulsions; and in infections with loss of tissue, as soon as the granulating bed is clean; (4) over fresh raw surfaces, if subcutaneous tissues are still present in the floor of the wound; and (5) as an intermediate step before the application of a full-thickness graft in obliterating osteomyelitic cavities.

Obviously the thicker the split-thickness graft, the better the coverage and the less the shrinkage. A thin graft or one of intermediate thickness, on a fresh raw surface or on a movable base, may contract as much as 60 per cent. When laid on a freshly denuded scar base, on periosteum, or in an area surrounded by tense skin, the shrinkage is less. Other factors that the surgeon will have to weigh are the available donor sites and the presence of infection. Should any question arise about the cleanliness of the recipient area, the surgeon would do well to err on the side of conservatism and choose a graft of lesser thickness, rather than risk the loss of a thick split-thickness graft.

The Mechanism of Take

The graft, securely sewed into the recipient area with adequate hemostasis and firm, even pressure, heals in a manner quite comparable to the healing of a bone graft. In about five hours the graft is firmly attached to the base by the formation of fibrin, and leukocytes and fibroblasts begin their invasion of the clot. According to Goldmann, for the first twenty-four to forty-eight hours the viability of the graft hangs in the balance, depending as it does upon the plasma and the lymph for its nourishment. In about eighteen hours endothelial buds, arising from the proliferation of the endothelium of the host blood vessels, begin to invade the graft. Padgett is of the opinion that endothelial buds connect with the endothelial spaces of the graft. He believes that the failure to connect with the endothelial spaces of the graft causes local degenerative changes to take place. This is the reason for sewing a graft into place under normal tension, so as to establish and maintain the patency of these endothelial spaces. Reichert demonstrated that the regeneration of small arteries across clean operative wounds occurs by the end of the second day, that veins and lymphatics become anastomosed by the end of the fourth day, and that the process is physiologically complete by the eighth day after operation. Davis and Traut believe that a graft is nourished, first, by the plasmatic circulation of Goldmann for the first twenty-four to forty-eight hours; second, by direct anastomosis between the vessels of the graft and the host; third, by the growth of capillaries of the grafted area into and along the degenerated vessels of the graft; and fourth, by the capillary upgrowth from the grafted area as it penetrates the connective tissue.

It is obvious, therefore, that the thicker the graft, the greater is the risk of failure. That is the principle which demands the removal of the fat layer from the free full-thickness graft; because of its greater thickness, death occurs before vascularization is complete.

In four or five days, organic union between the graft and the host is fairly firm. On the eighth day the blood supply is nearly complete. By the tenth day the two are united

by fibroblasts which, having invaded the clot by using the fibrin as a scaffold, connect the fibrous tissue of the two sites. The infiltration of fibroblasts into the graft is responsible for its contraction. Hand in hand with the proliferative changes—that is, the invasion of the graft by endothelial buds and fibroblasts—degenerative changes occur. The process can be likened to creeping substitution in the repair of bone. The exact mechanism is unknown. In the case of the elastic fibers in the graft, Padgett concluded that the elastic fibers degenerated and reappeared, "but not in the orderly manner which is characteristic of normal skin. Although the ultimate disorderly arrangement of the elastic fibers may have something to do with the tendency toward a glistening appearance of a skin graft, it is more likely that it is the replaced fibrous tissue which tends to obliterate the normal surface corrugations in the epithelium of the graft."

Exfoliation of the most superficial layers of the graft not infrequently occurs, and this varies in degree in direct proportion to the speed of vascularization of the graft.

Microscopic sections of the graft during this stage of adaptation not infrequently reveal collections of leukocytes at various levels. These, of course, are increasingly numerous as the grafts become thicker.

After the lapse of two or three months, the cellular infiltration disappears. The fibroblasts become mature compressed cells of fibrous tissue, and lose their plump, spindle-shaped appearance. A layer of fat of variable thickness is now found to line the deep surface of the graft, permitting it to move freely over the underlying tissue. The thickness of this adipose layer varies with the thickness of the graft, being more abundant in the full-thickness graft than in the split-thickness variety.

Full normal sensation usually develops in free skin grafts; it is influenced by the amount of deep scar tissue that is left behind, and depends upon the presence of sensory nerves in the area and on the thickness of the graft. The sensations of pain, temperature, and touch may develop as early as five weeks or as late as several months.

Because the skin on the palm or the sole is highly specialized, with a thick epithelial layer and a relatively thin dermal layer, metaplasia of free grafts—and, for that matter, of flaps—does not take place. Therefore, grafts in these areas must always be protected.

The Use of the Padgett Dermatome

The Blair-Brown knife-and-suction-box technique in the hands of the expert is excellent. With the Marcks attachment, its use has become more simplified; but with the invention of the Padgett-Hood dermatome, broader horizons have been opened up for the early replacement of lost skin. The means to select a graft of predetermined thickness has been placed in the hands of an operator. The dermatome has the following advantages: (1) Its mastery is comparatively simple and can be acquired by the average surgeon; (2) grafts of uniform thickness (four by eight inches) are obtainable; (3) it increases the number of available donor sites,—for example, the chest and the area over the ribs.

With the mechanical means at hand to obtain adequate split-thickness grafts, it is a matter of little experience to obtain surface covering. There are, however, certain important points to be observed in securing a graft. Every step must be meticulously carried out.

The drum, the brush, and the donor site must be absolutely dry; no trace of moisture must be present. It is well to go over the drum and skin with ether to assure the dryness of these areas.

The quality of the blade and its sharpness must be assured; it is placed in the instrument with the bevel away from the drum, and held in place by the clamp. It has been the author's practice not to use the same blade more than three times without having it re-sharpened. Ideally, of course, the blade should be sharpened after every use. Great care should be taken to avoid nicking the blade against the instruments and against the drum. It should be sterilized by cold sterilization.

The drum is now set at the predetermined thickness and placed on its rack, pending the preparation of the donor site, which will be described later.

The operator, having assured himself that the drum, the blade, and the donor site are clean and dry, is ready to apply the rubber cement. The cement is not poured until it is ready for use; if poured too soon, its volatile elements evaporate and the viscosity increases. The optimum viscosity of the cement is also a matter of importance. If too thick, ether should be added until the proper consistency is obtained.

In applying the adhesive, the drum is held in the left hand, with the back of the blade and the carriage resting on the operator's wrist. The brush should have fine bristles, about one and one-half inch to two inches wide. The cement is applied to the drum in a thin layer, with sweeping strokes. There must be no back-and-forth brushing; a thick layer of cement will dry unevenly and may invite failure. The edge of the drum should be adequately covered with glue, as this is the edge at which the blade engages the skin. Good adhesion between the skin and drum at this point is of utmost importance.

After the application of the cement to the drum, and while the drum is still being held in the left hand, the donor site is painted with the adhesive. The same precaution of smooth, even application of the cement is observed. Drying can be hastened by gently fanning with a folded sterile towel. The length of time required to dry the cement varies with the cement itself, its viscosity, the thickness of the application, the temperature of the operating room, and the humidity. Therefore, the time element cannot be estimated, but rather the dryness can be determined by the loss of the glistening sheen of the applied cement.

The edge of the drum is placed at the top of the donor site and pressed down firmly for a few seconds so that the entire edge of the drum is engaged by the skin. Then, by gently rolling the drum slowly, the blade is brought into action and, by a sawing motion, the desired amount of skin is obtained. This may be the size of the entire drum, or any portion of it. When the desired amount has been obtained, the drum is pulled at right angles to the skin surface and, with the blade still operating, the graft is severed from its attachment.

Failure of any steps necessary for the successful application and adherence of the cement to the drum and skin calls for immediate cessation of the procedure, which must be started again from the beginning. This means that every vestige of cement must be removed from the drum and the skin. Should blood or moisture be present on the drum or the donor site, it is scrupulously removed and the area is dried by sponging with ether.

The graft is now removed from the drum by grasping the edge with mosquito hemostats placed on the four corners of the graft. The small areas grasped and crushed by the hemostats are cut away before the graft is sewed into place. If the same precautions are used that one would exercise in the handling of adhesive tape, the graft will not become stuck to itself.

The graft is not placed in saline before use, but is merely placed in the folds of a damp towel, or the cut surface is folded on itself. If the graft were allowed to soak in a basin of saline, the serum in the endothelial spaces would be washed out, small amounts of natural adhesive agents present would be removed, and the take of the graft might be jeopardized.

It may appear from this discussion that the technique of obtaining the split-thickness graft by means of a Padgett dermatome is difficult. This is not so. With a reasonable degree of attention to the details involved and with average skill, the graft is obtained easily.

THE USE OF THE SPLIT-THICKNESS GRAFT

Three types of wounds must be recognized for the successful use of a split-thickness graft: (1) the wound accidentally incurred within a period of a few hours; (2) the wound created surgically following the excision of a scar; and (3) the granulating wound.

The granulating wound may be the result of a burn, an infection, or an avulsion of skin. The management of each of these three types must be different to assure the greatest number of successes.

1. *The Treatment of the Early Traumatic Wound*

The accidentally incurred wound, if seen within six hours, can be treated in the same manner as the surgically excised scar. It is true that the wound is contaminated, but infection is not present. Organisms exist in small numbers, but they have had little opportunity to multiply or to penetrate deeply into the tissue. They can be removed by mechanical cleansing and by débridement. If important structures—such as bones, major blood vessels, nerves, or tendons—are exposed in the wound, it is well to undermine the edges widely to afford primary coverage for them. If insufficient skin is present to allow for such closure, a relaxing incision—well removed from the skin edges and over unimportant structures—is made and the skin is slid over. The defect produced by the relaxing incision is then treated by the insertion of a split-thickness graft. If the defect is of such great size that these methods are not applicable, a broad-based flap can be raised and sutured into place immediately, or a pocket graft may have to be considered. These procedures are beyond the scope of this paper. However, if the wound is more than six hours old, it must be considered as infected and treated by the methods described later.

It should be emphasized that a very early accidental wound or a wound due to the excision of a cicatrix can be treated as a clean wound, but the granulating wound must always be treated as an infected one. The principles of treatment differ radically one from the other.

2. *The Treatment of the Aseptic Wound*

By an aseptic wound is meant one that has been created by the excision of a cicatrix.

The donor and recipient sites are prepared twenty-four hours in advance of the operation by shaving, washing with Castile soap and water, followed by washing with ether and alcohol, and wrapping in sterile towels.

The patient is brought to the operating theater, where the final preparation of both sites is undertaken. After scrubbing the hands in the prescribed manner for ten minutes, the surgeon or his assistant dons a pair of rubber gloves and proceeds with the preparation of the skin. This is done by washing the areas eight or ten minutes, using soap, water, and gauze. The soap is removed by pouring copious amounts of water over the area. Germicidal solutions are not used, since the author believes that they have no advantage over the soap and water, and are even harmful to the graft. The surgeon now discards his gloves and, after using the operating-room solutions again, puts on his operating gown and new gloves. The donor area is draped in the usual manner, and in such a fashion that ample freedom for the operation of the dermatome is available.

A solution of 0.5 per cent. procaine, containing six to eight drops of adrenalin to the ounce, is used to infiltrate the scar bed. The procaine is not used for its anaesthetic value, but merely as

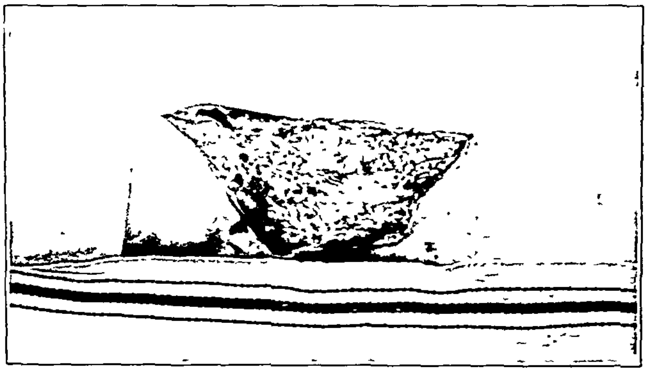

Fig. 1

Contracture of the popliteal space after a burn; shows the aseptic wound. Note (1) complete excision to normal unscarred tissue; (2) complete hemostasis; and (3) staggered line of excision.

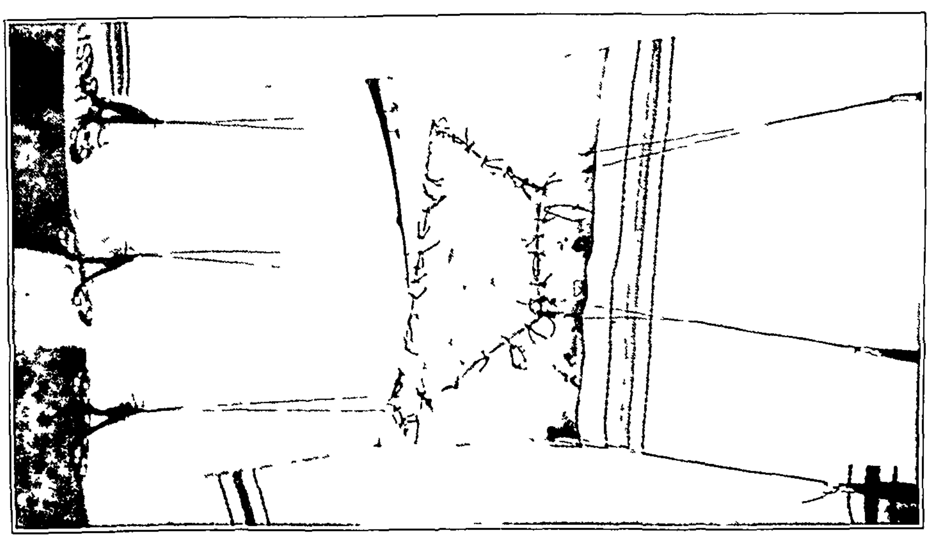

FIG. 2

Graft has been sewed into place under normal tissue tension. Stay sutures have been used in recipient area, with "pie-crusting" of graft.

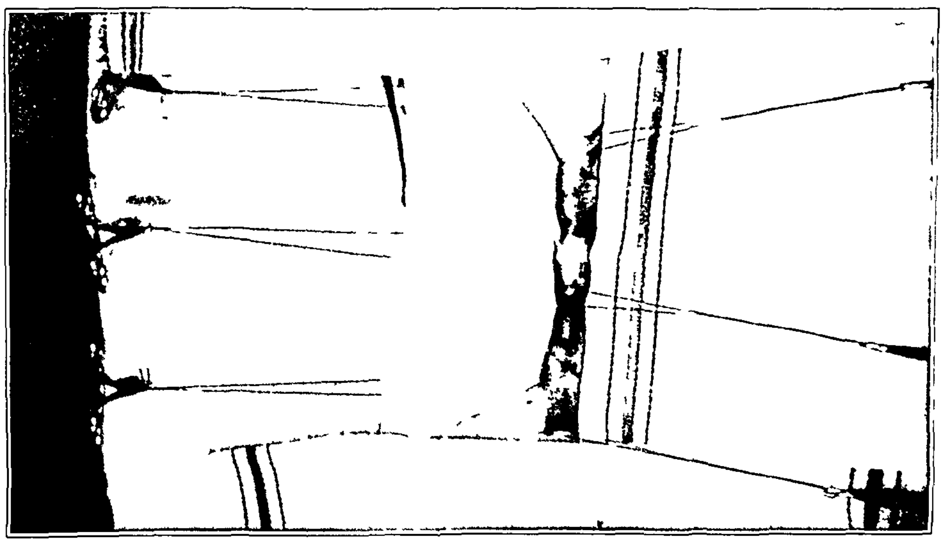

FIG. 3

Xeroform gauze (44 by 40 mesh) has been impregnated with 3 per cent. solution of bismuth tribromphenate. The gauze, two layers thick, has been laid smoothly, without wrinkles.

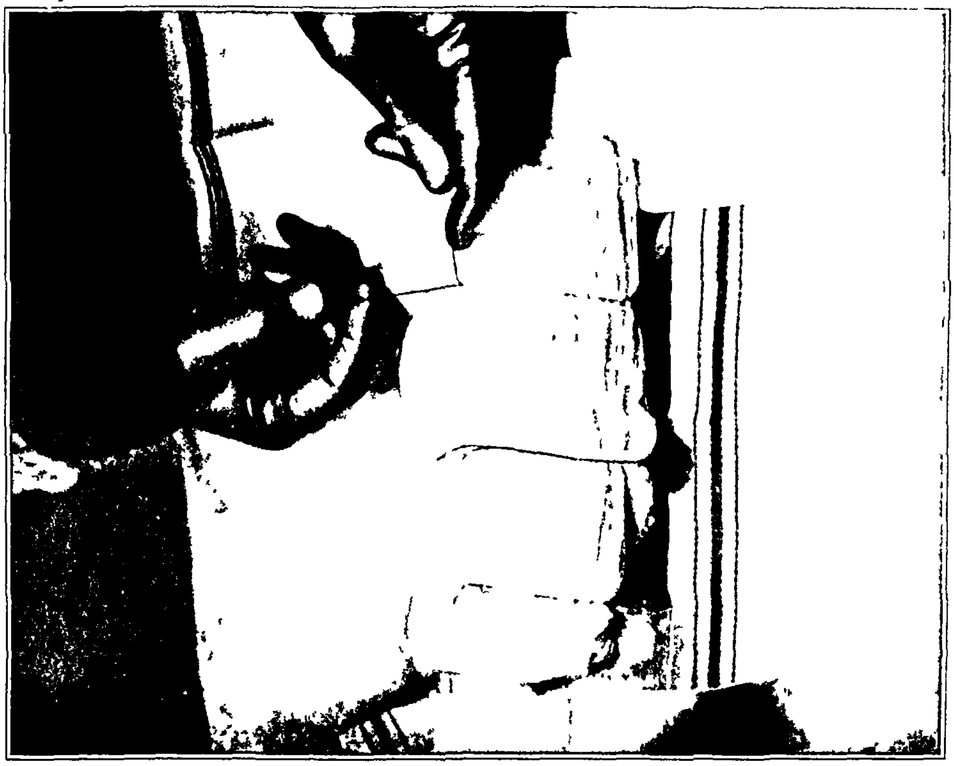

FIG. 4

Dressing is being tied into place with stay sutures to exert firm, even pressure and to prevent displacement of dressing. If this patient had had a late traumatic wound or a granulating wound, catheters would be placed at this level.

FIG. 5

Shows voluminous dressing of fluffed, washed gauze sponges. Dressing surrounds entire limb; over these fluffed sponges are laid large laparotomy pads.

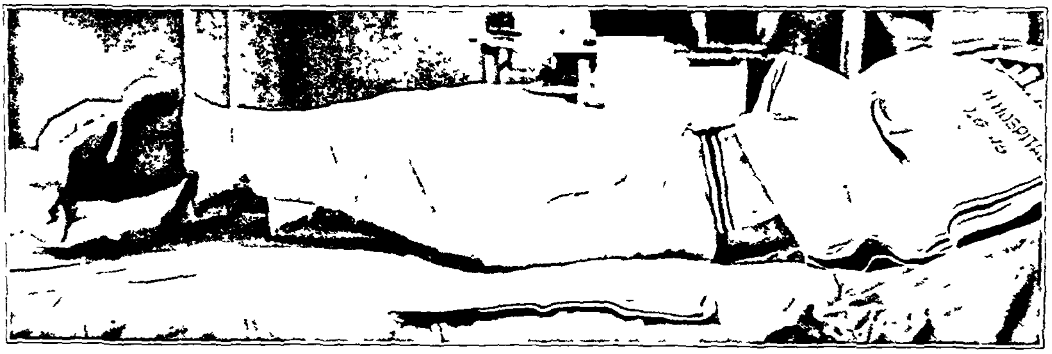

FIG. 6

Shows final dressing, with bias-cut stockinette bandage, extending from ankle to above grafted area.

a vehicle to convey the adrenalin. The adrenalin assures a dry bed until the graft has been sewed into place and the compression dressing has been applied.

If the area will permit, a tourniquet is used and the adrenalin solution may then be dispensed with. The pneumatic tourniquet is preferred, particularly in the upper extremities. This tourniquet or a blood pressure cuff is inflated to 260 millimeters of mercury. Because skin-grafting is a long procedure, it is advisable to release the constrictor for a few minutes after the lapse of forty-five minutes.

Excision of the scarred area is now undertaken. This must be complete, and the underlying normal tissue must be exposed. The area to be excised is outlined with gentian violet, 5 per cent. brilliant green in alcohol, or Bonney's blue solution. The suture line, which contracts in its long axis, is staggered by the making of gores in the excising incision. In this way is prevented the formation of bands, which frequently give rise to imperfect results.

Perfect hemostasis is absolutely essential for success. This is obtained, first, by the adrenalin solution or the tourniquet. A blood vessel that requires tying should be ligated with the finest silk obtainable, and the knot cut short. Small vessels often can be treated by crushing and torsion. The use of the coagulation current is not favored, as it leaves a small mass of necrotic tissue, which may vitiate the result of the graft. The use of an absorbable suture is condemned; it gives rise to an inflammatory exudate for its absorption, and therefore is prejudicial to the success of the graft. Hot saline sponges applied locally are useful to control the oozing from capillaries. Many surgeons are thoughtless in the use of hot saline sponges; a sponge which is too hot for the surgeon's gloved hand is

obviously damaging to the tissue. The temperature of hot sponges should not exceed 120 or 130 degrees Fahrenheit.

Brown and McDowell[4] state that sulfanilamide may be dusted sparingly over the bed. The author agrees with their observation that an excess amount of the powder interferes with the graft, and prefers to rely upon the surgical principles of moisture and adequate drainage.

The graft is now sewed into place. It should be so planned that the maximum area is covered without piecing. If the area is so large that it requires more than one drum of skin, the sections may be pieced before being sutured to the defect, as was recommended by McPheeters and Nelson,—the so-called "blanket graft". The graft is handled with great gentleness, with skin or dural hooks; the use of tissue forceps is not permissible. The graft is sewed into place with interrupted sutures of Size 6–0 silk. The advantages are twofold: First, better cosmetic results are obtained; and second, the silk is so fine that it will not withstand a great deal of tension and will tear long before the tissue is strangulated by too tight a suture. Such a fine suture material may try the patience of the novice, but it pays handsome dividends to those who learn to use it successfully. As stated previously, the normal skin tension of the graft is important to the success of the operation. After anchoring the graft at one point, the edge is picked up with a dural hook and is stretched to the point where its elasticity almost disappears. At that point it is fixed to the incised edge of the recipient area.

Small incisions are made into the graft with a No. 11 Bard-Parker blade, to allow for the egress of any collections of blood or serum. "Stay" sutures are now placed around the periphery of the wound in the recipient area; these are left long (Fig. 2). One or two thicknesses of 3 per cent. xeroform gauze, on fine 44 by 40 mesh, are laid smoothly, without wrinkles, over the graft, with slight overlapping of the sutured edge (Fig. 3). Over this are placed ten or twelve layers of ordinary gauze, which are tied snugly into place by means of the stay sutures (Fig. 4). Tying the dressing into the wound prevents shifting of the dressing and tenting, and helps to apply firm pressure so that serum cannot collect beneath the graft. The author agrees with Brown and McDowell[4] that vaseline gauze tends to cause maceration of the tissue; whereas any powder added to it, such as sulfanilamide, xeroform, scarlet red, or boracic acid, prevents maceration. After the dressing has been tied into place, voluminous fluffed gauze, mechanics' waste, or sea sponges are placed around the circumference of the limb, and all are held in place by a stockinette bias-cut bandage (Figs. 5 and 6). The voluminous dressing frequently affords adequate immobilization; if not, it may be supplemented with immobilizing apparatus.

Important as are the cutting of the graft, the preparation of the recipient area, the absence of infection, and complete hemostasis to a successful take, the application of the dressing is of no less importance. The preparation of the recipient area, the cutting of the graft, or the sewing of the graft into place may be delegated to the assistant, but it is a surgeon's responsibility to apply the dressing.

The recent literature has many references to new methods of application of split-thickness grafts. It might be well to examine these methods in the light of surgical principles.

In 1943, Sano introduced the coagulum contact method of affixing the graft to the recipient bed. This followed the observation that growth of tissue culture was obtained uniformly and successfully when cells were supplied with a suitable surface for growth through the use of coagulated plasma, and when adequate nutrition—through the medium of embryonic tissue extract in a buffered salt solution (Tyrode's solution)—was present. The most satisfactory results were obtained by the use of homologous plasma and tissue extract.

Later that year Sano, Holland, and Babcock described the method of making the two solutions for coagulum contacts. One milligram of heparin was added to five cubic centi-

meters of blood and centrifuged. The blood separated into three layers: the supernatant plasma, a layer of leukocytic film (the so-called "buffy coat"), and the red corpuscular layer. The plasma is poured off and is called Solution A. The buffy coat is removed with a platinum loop, and placed in a sterile test tube containing three cubic centimeters of Tyrode's solution; and a cellular extract (Solution B) is made by shaking the solution vigorously with sterile glass beads. The recipient area is flooded with Solution A and the graft is painted with Solution B; when the two surfaces are brought together, coagulum fixation occurs. It has been advocated for the Reverdin, Davis, and Thiersch types of grafts, for split-thickness dermatome grafts and full-thickness grafts, on granulating or fresh wounds. The proponents claim its superiority chiefly on the basis that the adhesion is so perfect that suture and pressure dressings are unnecessary.

Cohn and his associates, having isolated the thrombin and the fibrinogen fractions of plasma, have simplified the method considerably. The thrombin in aqueous solution is sprayed with an atomizer and is applied to the graft. The fibrinogen is applied to the recipient surfaces.

The writer has had insufficient experience with the procedure and therefore reports the results of other observers. Young reports as follows: In twenty-six cases of split-thickness grafting, there was 100 per cent. take in twelve cases of primary grafts. In four cases of fresh traumatic contaminated wounds, there were 48 per cent. takes. In ten granulating wounds, a 59 per cent. average take was estimated; in two of these cases the graft was totally lost. Young concludes that "it is our definite impression that the loss of grafts is considerably greater on infected wounds when applied by this method than when compression dressings are used. This applies to contaminated fresh wounds as well as to granulating beds. It is probable that infection is sealed under the graft, drainage is poor and the result is a purulent collection under the graft which prevents vascularization."

Jenney states that he, J. Eastman Sheehan, and Lawrence Gatewood found that pressure dressings and immobilization are essential for best results with the Sano technique. This ensures perfect apposition of the graft to the recipient area and prevents air pockets, oozing, and blood accumulations.

It would thus appear that the coagulum contact method does not fufilll the surgical principles of maintenance of normal tissue tension and firm, equalized pressure; and it ignores the concept that all granulating wounds must be considered infected, and therefore must be treated by moist dressings. Davis and Traut, in 1925, and Davis in 1927, emphasized the need for maintenance of normal tissue tension and stated: "We also found that the contraction of the elastic fibers in the skin occluded the vessels, and for that reason when securing the graft in position, we apply tension equal to that of the normal skin to overcome this tendency".

If one ignores the absence of tissue tension—and it is a factor that cannot be lightly disposed of—it is obvious that in the freshly created surgical wound the graft may take well; but in the presence of potentially infected wounds—that is, granulating surfaces and contaminated traumatic wounds—proteolytic enzymes are liberated from degenerating white cells, and digestion of the fibrin takes place.

Koch states that "only in unusual instances are we willing to lay a flap, with an assured blood supply through its pedicle, over a granulating surface, so concerned are we over the destructive effect of even a few bacteria on the vulnerable subcutaneous tissue which forms the undersurface of the flap".

The author, therefore, is compelled to conclude that the Sano technique has a very limited application and does not fulfill the basic requirements of sound surgical principle in so far as split-thickness grafts in unclean wounds are concerned. If the technique is extended to include such factors as the maintenance of normal tissue tension and firm, equalized pressure, and the application of moist dressings in the potentially infected wound, it offers very little advantage over the conventional method of graft suture.

A great deal has been written about the desirability of cutting a graft according to the exact pattern of the defect. To the writer, this objective is unsound and worthless. The donor site in a split-thickness graft has present all the elements necessary for regeneration. A donor site, from which a graft has been removed, heals as well and as rapidly if ten square inches or the maximum of thirty-two square inches have been removed, provided adequate after-care is given. In removing skin for a graft, it is well to take somewhat more than is required, but to cut exact patterns is wasteful of time and effort and serves no useful purpose.

Other writers have advocated the cementing of nylon, plioform film, cellophane, bobinette, or other material to the drum, and then taking the graft in the usual manner by painting this material and the skin. This is so that normal tissue tension may be maintained by the transfer of the skin and the material which is adherent to it. Another alleged advantage is that it saves time and does not require suturing to the bed. In the author's opinion, these additions to technique are not only unnecessary, if one adheres to the sound surgical principles of the management of split-thickness grafts, but are not time-saving, because the time necessary for the application of the material to the drum could well be used for suturing the graft into place.

3. *The Treatment of the Granulating Wound*

The optimum time for transplantation of skin to a granulating bed is of first consideration. A great deal has been written about the bacterial content of the granulating wounds. Lange has described the intravenous use of ten cubic centimeters of 5 per cent. fluorescein buffered with 5 per cent. sodium bicarbonate; the area is then inspected in the dark room under the influence of a mercury vapor lamp, screened to emit 3,600 Angström units. An adequate blood supply to the part is determined by the appearance of an intense golden-green color in from fifteen to twenty seconds; an inadequate blood supply is evidenced by a dark purple or slightly bluish-green color. Sheehan has advocated the determination of the oxygen and sulfur content of the skin as an index for grafting. These studies are of academic interest only, and can be dispensed with. The most useful criterion is the appearance of the ulcer itself. It should be free from grayish slough or gross pus; the exudate should be thin and scanty; the granulations should be firm, pink or red, should present a cobblestone appearance, and should be flush with the skin surface. They should not be pale, anaemic, exuberant, or oedematous. Healthy granulation tissue bleeds easily on irritation and is relatively painless. Epithelial ingrowth from the edge, which presents a beveled appearance, is observed in the healthy ulcer. There should be no surrounding redness, inflammation, or cellulitis, or heaping up of epithelial debris.

To assure an adequate granulating surface for a successful split-thickness graft, one must be guided by general constitutional and local factors.

General Constitutional Factors: Grafts do not take well in patients with chronic debility, or in the presence of anaemia, hypoproteinaemia, dehydration, avitaminosis, oedema, or disturbance of the electrolytic balance. Furuncles, either local or remote, are inimical to grafts. In children, grafts take better than in the aged, but the difference is not marked. When the hemoglobin is reduced to below 65 per cent., the percentage of take decreases from one-third to one-half. It is obvious that general treatment must be directed toward the correction of such abnormalities.

Local Factors:

Granulation tissue is infected tissue and, in preparing such an area for the application of the graft, we must rely upon sound surgical principles of cleanliness, rest, elevation, free drainage, and moist dressings which afford moderate compression. Ointments and dry gauze are contrary to sound surgical judgment. They favor retention of secretions and prevent adequate drainage. The author believes that local application of the sul-

fonamides, gramicidin, or penicillin is not necessary, but may be used as an adjunct. Local trauma to the granulation tissue must be sedulously avoided. Fine mesh gauze (44 by 40) is laid over the raw surface. This prevents the granulations from growing into the interstices of the gauze and being pulled off with each change of the dressing. The solution used for moist dressings is in itself of little moment. It can be normal salt solution, boracic acid, or magnesium sulfate. The principal consideration is not the specific property of the solution, but the moisture supplied, which promotes the flow of lymph and provides drainage.

Pyocyaneus infection is particularly hazardous to the successful take of a graft. Although Blair and Brown recommend the frequent painting of the area with gentian violet or methylene blue, the use of proprietary mercurials, and copious use of soap and water, and although they look with disfavor upon the use of hydrogen peroxide and acetic acid, it has been the author's experience that the use of acetic acid in strengths of from 0.5 to 2 per cent., before and after operation, has met with uniform success.

Objections may be raised that continuous moist compresses result in maceration of the tissues. It has been the author's experience that, when moist dressings are used in conjunction with a voluminous dressing, moderate pressure, and elevation, maceration does not occur, because the circulation is well supported and the compression dressing prevents water-logging of the tissues. It is also noteworthy that pale, flabby, oedematous granulation tissue under the influence of elevation, moisture, and pressure rapidly becomes firm, pink, and healthy in appearance.

The Management of the Split-Thickness Graft in Granulating Wounds:

It is advantageous to have a competent assistant in planning extensive skin-grafting. If the recipient area is a granulating wound and hence must be considered infected and unclean, the operator, if he works alone, works from the clean field to the unclean. He takes his graft first and then prepares the recipient bed. With a competent assistant, however, the taking of the graft and the preparation of the recipient area can be done simultaneously by the operator and his assistant, working independently in the different areas. In this way the operating time can be shortened measurably.

Assuming that the granulating surface has fulfilled all the conditions necessary before skin transplantation is undertaken, the epithelial edge is circumcised by sharp dissection. This is important because, without the removal of this tissue, there is an irregular, unsightly area of union between the graft and the host.

The question may be raised as to the management of the granulating wound at the operating table. Authorities differ as to whether one should remove the base or leave it in place. It has been the author's practice to leave the granulation tissue, if it is of recent origin and short duration. If the ulcer is old and calloused, it is advisable to remove the granulation tissue by sharp dissection—never by scraping—to the smooth yellow base, which has a satisfactory blood supply. At times it is possible to excise the ulcer *in toto,* and place the graft on the normal underlying tissue. In old cases with contracture, one may crosshatch the base and correct the contracture before the application of the graft.

The graft can now be sewed into place. Attention should be paid to hemostasis, gentleness of handling, sewing the graft into place under normal tissue tension, placing of basting sutures if there is any tendency to tenting, and "pie-crusting" the graft with multiple small incisions.

Up to this point, the techniques of surfacing the aseptic, fresh traumatic wound and the granulating wound parallel one another rather closely; but from this point on the techniques diverge. In the aseptic or recent traumatic wound the dressings may be dry, but in the granulating wound—because it is potentially infected—the dressings must be wet. This is a fundamental concept, with which there can be no compromise if uniformly successful results are to be expected.

Stay sutures of medium silk are placed one-half inch from the graft, around the

periphery. Usually two or three are required on each side, external to the recipient area. The graft and the surrounding tissue are sponged off with hydrogen peroxide. The purpose of this is to enable the operator, on subsequent visits to the patient, to detect, by the odor of the dressing, the presence of suppuration or pyocyaneus infection without the mingled odor of dry or stale blood. Bandage gauze of the finest quality, 44 by 40 mesh, eight to ten layers thick, is now cut to pattern so as to overlap the margin of the graft. This is wrung out in normal salt solution and laid smoothly, without wrinkles, upon the graft. This may appear to be an unimportant step; yet, at the point at which wrinkles occur, failure of the graft to take may result. Moistened gauze dressings, laid smoothly, are placed over the bandage gauze, and the whole is tied into place with the stay sutures. As pointed out previously, this is of material help in exerting firm, even pressure over the graft, and prevents the dressings from sliding and becoming misplaced. Two or three No. 18 French catheters, with additional holes cut into their distal ends, are now placed over the dressing in a radial fashion. Over this and surrounding the entire limb are placed moistened mechanics' waste, fluffed, washed gauze sponges, or sea sponges, and the whole is covered with a large laparotomy pad. It is important that voluminous resilient dressings surround the entire limb, and are not placed merely over the grafted area, in order to exert uniform pressure over the whole limb. Holding all these dressings in place is a stockinette bandage, which is cut on the bias, six to eight inches wide, from tubular stockinette. The advantage of this over the conventional elastic or crepe bandage is that it can be cut in far greater length than the usual five and one-half yards. This bias bandage is applied snugly from the most distal part of the limb to well beyond the grafted area. In this manner, it exerts even pressure over the grafted area and supports the circulation above and below the graft. One need have very little concern about the tension of this bandage if a truly voluminous dressing has been applied, for the writer has never seen embarrassment of the distal circulation.

The question of immobilization is the next concern. If the dressing has been voluminous, very little additional immobilization is necessary. If in the opinion of a surgeon, however, immobility is incomplete, basswood, a pillow, or a Thomas splint may be used to advantage. A plaster-of-Paris cast is definitely contra-indicated, as it softens from contact with the moist dressing and interferes with the evaporation of the surface moisture. In addition, it is heavy and cumbersome.

The after-care of the grafted area is of utmost importance to the success or failure of the operation. Without interruption, the dressings must be moistened by means of the catheters every four hours, day and night, with boric-acid solution or normal salt solution. This is important, because it makes up for the loss of moisture from surface evaporation. If the area was the seat of pyocyaneus infection, it has been the author's custom to omit one or two injections of boric-acid solution or normal salt solution and to use instead a solution of acetic acid in strengths of from 0.5 to 2 per cent. This has been very effective in controlling the pyocyaneus.

The purpose of using moist dressings in granulating wounds is that the moist solution, in contact with the grafted area, promotes the flow of lymph to the bed, and so offers nourishment to the graft. It prevents the formation of crusts, which would block drainage. Evaporation of moisture from the surface of the dressing causes good drainage, because, as fluid is delivered to the bottom layers of the dressing, by capillary action the fluid rises to the surface. Evaporation on the surface augments the effectiveness of the drainage. Maceration of the tissue does not occur.

Important as it is to supply a sufficient amount of solution to the dressing—and this, of course, varies with its size—it is just as important not to supply too much. The dressing must not be so wet as to lie in a pool of solution. Neglect of this precaution is most dangerous to the graft, for the dressing lying in a pool of liquid acts as a wick, and unsterile solution is brought to the grafted area by the same process of capillary action.

When the correct amount of fluid is being supplied, the outer surface of the dressing should feel only slightly damp.

Dressing of the Donor Site:

The skin of the donor site regenerates by virtue of the fact that the epithelial elements of the skin—that is, the sweat glands and hair follicles—are left behind.

In order to avoid pain and discomfort, and to ensure proper healing of this area, extreme care must be taken in the dressing. Although numerous methods have been advocated, such as tanning with escharotics, or the application of silver foil, it has been the author's experience that the most suitable dressing is the one in which firm pressure is secured against motion.

After the graft has been obtained, the donor site is temporarily covered with a towel, wrung out in normal salt solution. The towel is in intimate contact with the donor site, and is undisturbed until all procedures in the recipient area are completed and the dressing has been done. After this, strips of 3 per cent. xeroform gauze are laid smoothly upon a large abdominal pad. While the assistant removes the towel over the donor site with alacrity, the surgeon without loss of time places the xeroform-covered abdominal pad over the site. Firm pressure by the assistant is maintained until additional soft pads are placed about the circumference of the limb, and the whole is bandaged snugly with a bias-cut stockinette bandage.

This may appear to be a surgeon's fetish, but sound principles are involved. The moist towel over the donor site arrests the punctate bleeding from this area. Its removal, because of its adherence, causes fresh bleeding which, if allowed to be present under the dressing, acts as a nidus for infection. It is, therefore, advisable to effect the transfer of a xeroform-covered pad for the moist towel with a minimum loss of time, and to maintain even pressure throughout the healing period with the bias-cut bandage.

If the patient is afebrile and daily inspection of the dressing reveals no suppuration, the dressing is left undisturbed for fourteen days; at this time it is removed, and the area will be found to be completely epithelialized. The dressing is always firmly adherent to the epithelialized donor site. Care should be exercised in removing the dressing not to strip off the delicate epithelium. Soaking with peroxide or normal salt solution is unnecessary, but gentleness is imperative. The use of a hemostat, to depress the skin gently as the dressing is removed, is of inestimable assistance. No further dressing is necessary. A protective emollient, such as 2 per cent. boric ointment, is sufficient to keep the skin soft.

At the end of two weeks the donor site is of a bluish color. This pales out in several months and leaves an area slightly lighter in color than the surrounding normal skin.

Postoperative Care:

Routine postoperative surgical care is supplemented with special attention to the graft. The limb is elevated; a Thomas splint or a pillow splint is very useful for this purpose. Dependency of the part is prohibited; under no circumstances is the use of crutches permitted, in the case of the lower extremity, until healing has been completed. Dependency may produce stasis in spite of the pressure dressing, and this is detrimental to the graft.

Two things are relied upon to determine the state of the grafted area without its actual exposure. These are the surgeon's sense of smell and the patient's temperature. The surgeon should sniff of the dressings at each visit, not casually or disdainfully, but by lifting a few turns of the stockinette bandage with his fingers and bringing his nose into close proximity to the dressing. This is done at several points, particularly around the edge.

The other indicator of the status of the graft is the patient's temperature. A slight elevation of temperature for from twenty-four to forty-eight hours is expected. Thereafter

the patient should be afebrile. The odor of suppuration or of pyocyaneus infection, or a persistent elevation of temperature should call for immediate inspection of the graft.

The donor site should not be overlooked. It, too, must be inspected daily and sniffed, because occasionally that area may be the seat of trouble. This is particularly true if the patient complains of a great deal of pain. It is not uncommon, however, to have patients complain of slight discomfort from the close adherence of the dressing to the donor area. Should infection occur in this region, the compression dressing is removed; and warm, moist dressings, such as would be used for any infection, are substituted.

There appears to be considerable confusion about the time of changing the initial dressing. Dogmatically, from ten to fourteen days has been set as the most propitious time for changing the dressing. Nothing could be more erroneous. There is no adequate reason why the graft should not be inspected at an earlier date. In fact, there are definite advantages to inspecting the graft much earlier. If a small clot, or a collection of serum or blood is present, that area may be saved by timely incision for evacuation of such fluid. Sometimes a suture may have been placed too tightly and may be causing strangulation of the tissues, and its early removal may prevent loss of that part. Occasionally mild infection may be present. Severe infection is beyond the hope of rescue; but, in the case of mild infection, an incision for the establishment of drainage and the immediate institution of moist compression dressings may save a large part of the graft. At times, small areas of dry gangrene of the graft are present. These can be recognized by their circumscribed, dry, brownish character; and, if small, they are of no great moment. The area is lost; but, as it is seldom larger than a five-cent piece, it becomes epithelialized from the remainder of the graft and there is no great difference in the end results. Should an area be definitely beyond the hope of saving, there should be no hesitation in excising it. The procedure is painless and can be performed at the bedside.

If the wound was an early traumatic or an aseptic surgical wound, the graft is inspected on the sixth or seventh day. If it was a granulating wound, the graft is inspected on the third or fourth day. If the patient is febrile, the graft is inspected at an earlier date.

Upon inspection of the graft in the first week, it may present a mottled appearance. Some areas, or the entire graft, may appear cyanotic. This is not to be interpreted as death of the graft, but rather as incomplete vascularization and diffusion of blood pigments. In such cases, it is well to continue with moist dressings until all such discoloration disappears.

Should the graft be dry, pink, and adherent to the base, one may apply a layer of gauze (44 by 40 mesh), without wrinkles, impregnated with 3 per cent. xeroform. Over this is placed a voluminous dry pressure dressing. This dressing is changed every three or four days for about three weeks. At the end of this period all dressings are discontinued, and 2 per cent. boric ointment is applied to keep the graft and the surrounding skin soft.

If there is any question about the status of the graft during the immediate postoperative period, one should at once revert to wet, voluminous pressure dressings.

Sutures are usually removed in two stages: Alternate sutures, or sutures that appear to be causing embarrassment to the circulation of the graft, are removed at the first dressing; the remainder at the end of ten days. At the first dressing of the graft, it is advantageous to cut the stay sutures in such a manner that they may be used again to tie the new dressing into place.

CONCLUSIONS

1. The split-thickness graft offers a wide range of usefulness, and, with average skill and a reasonable amount of diligence to the details involved, it is easily obtained by the average surgeon with the Padgett-Hood dermatome.

2. Three types of wounds requiring split-thickness grafts must be recognized: the early traumatic wounds, the aseptic wounds caused by the excision of a scar, and the

granulating wounds. Each requires different management. Early traumatic and aseptic wounds may be considered clean and dressed dry; the granulating wound or the late traumatic wound must be considered infected and unclean, and must be dressed with moist pressure dressings.

3. Newer methods in the handling of the split-thickness grafts must be measured by the yardstick of sound surgical principles. With these principles there can be no compromise.

4. Skin-grafting to resurface lost integument for the correction of contractures, and to supply adequate coverage for weight-bearing surfaces and areas exposed to trauma, may come in the field of the orthopaedic surgeon. The procedure requires infinite attention to multitudinous details in preparing the recipient area; the obtaining of the graft of a desirable thickness; perfect hemostasis; the maintenance of normal tissue tension; the prevention of tenting; the close application of a voluminous pressure dressing; and the utmost gentleness.

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NEUROECTOMY TO PRODUCE ATROPHY OF THE AMPUTATION STUMP *

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Following amputation below the knee, the most satisfactory stump is one which is conical in shape and the maximum accepted length of seven to nine inches, as measured from the lower border of the patella.

The most satisfactory amputation stump observed by the author was on a young man who had extensive involvement of the muscles below the knee, due to infantile paralysis, but who had good power in the muscles of the thigh. In an effort to reproduce this type of stump, in four cases the author has divided the muscular branches of the tibial nerve to the two heads of the gastrocnemius, and in one case has also divided the nerve branch to the soleus, with very satisfactory results.

OPERATIVE TECHNIQUE

A longitudinal incision, two and one-half inches in length, is made in the lower part of the popliteal space, extending down the leg. Upon incising the deep fascia, the operator will observe the medial sural cutaneous nerve; this structure should not be damaged. This nerve may be used as a guide, to follow down into the popliteal space to the tibial nerve. The muscular branches of the tibial nerve to the two heads of the gastrocnemius are identified and completely sectioned. The branch to the soleus leaves the tibial nerve at a lower level, but is within the operative field, and may be sectioned.

Very little bleeding is encountered, but, before closure, all points of bleeding should be controlled to assure a dry field. The fascia and skin should be closed carefully to obtain a minimum amount of scar. The location of this incision is such that the scar has not been objectionable.

POSTOPERATIVE CARE

After operation, the knee is immobilized, either by traction or by a well-fitting posterior plaster splint, to facilitate healing of the wound in the popliteal space. After the amputation wound is well healed, the stump is bandaged with an elastic adhesive bandage. This support is maintained by changing the bandage every two to four weeks, until an artificial limb can be worn.

COMMENTS

The operation recommended can be carried out at the time of the amputation, after the tourniquet has been removed, by turning the patient onto his abdomen; or it may be carried out as a separate procedure, either before or after the amputation. The sural nerve and the tibial nerve should not be cut or damaged at this level, because of the danger of development of a painful neuroma.

This operation is of particular advantage in large-muscled adults, and, on the basis of limited experience, it would seem that the cases treated in this manner show a more rapid and complete atrophy of the amputation stump than others.

By producing a conical-shaped stump, this operation permits the surgeon to leave a stump of maximum length.

CASE REPORTS

Case 1. J. K. (No. 10,114), a white male, aged forty-two, was first seen on April 24, 1941, with a swollen below-the-knee amputation stump which had not healed. On February 26, 1941, this patient had

* Presented at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 23, 1946.

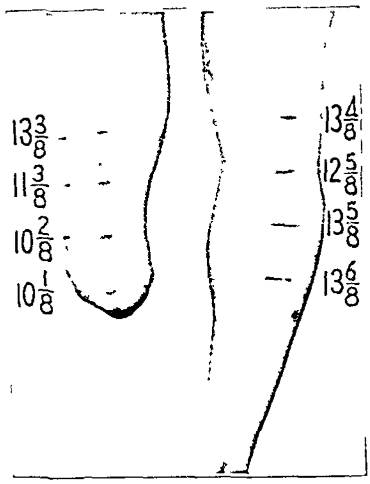

Fig. 1-A

Fig. 1-B

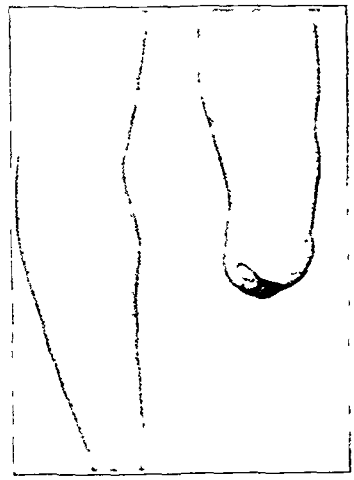

Fig. 1-C

Case 1. January 15, 1946.

sustained an injury to the right foot, which required immediate amputation. The wound had closed, but later spread open.

Physical examination disclosed a large man whose right leg had been amputated at a point eight and one-half inches below the knee. There was considerable swelling of the stump, and on the end there was a large granulating area, three and one-half by two and one-half inches in size.

The condition of the tissues was such that the stump was not suitable for re-amputation. On June 16, 1941, therefore, through an incision in the popliteal space, the muscular branches of the tibial nerve to the two heads of the gastrocnemius were sectioned. The granulating area on the stump was then covered with split-thickness skin grafts. These grafts closed the area, and the patient was discharged from the hospital on July 6, 1941, wearing an elastic bandage on the stump. On September 18 an artificial limb was applied, and the patient returned to work on January 1, 1942.

Because of a painful, thick scar over the end of the stump, the leg was re-amputated on November 25, 1942; this shortened the tibia about one inch. A new artificial limb was provided three months later.

TABLE I

Measurements in Case 1*

	Apr. 24, 1941		June 13, 1941		Sept. 11, 1941		Mar. 8, 1943		Jan. 15, 1946	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Length of tibia (*inches*)	8½	14			8½	14	7¾	14	7½	
Circumference of leg (*inches*):										
At knee			13½	13½						
Lower border of patella	13	12⅞			13	13	13½	13¼	13⅜	13½
2 inches below patella			13¼	13⅜			11	13½	11⅜	12⅝
4 inches below patella			12¾	13¾					10¼	13⅝
5 inches below patella	13¼	13¼			11	13¼	10½	13½		
6 inches below patella			11½	12¾			10½	12	10⅛	13¾
8 inches below patella	13¼	10			9¾	10				

*Operative procedures carried out on the following dates:
Guillotine amputation of right leg: February 26, 1941.
Neurectomy and skin graft: June 16, 1941.
Re-amputation: November 25, 1942.

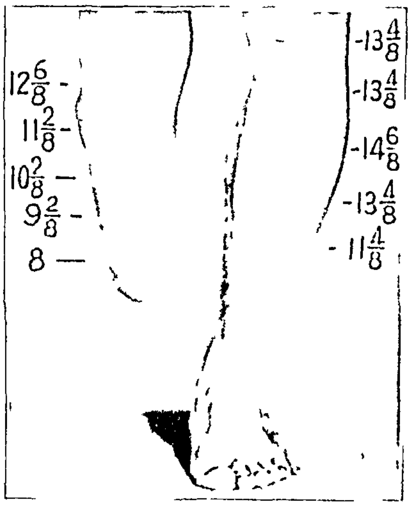

FIG. 2-A

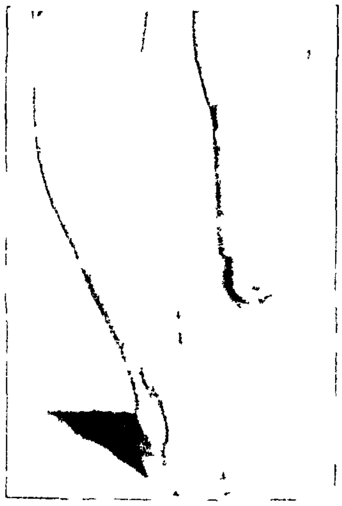

FIG. 2-B

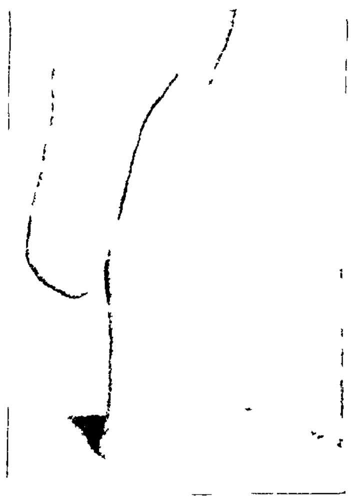

FIG. 2-C

Case 2. December 22, 1945

TABLE II

MEASUREMENTS IN CASE 2

	Dec. 31, 1942		Jan 23, 1943		Mar 11, 1943		Sept 5, 1944		Dec 22, 1945	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Length of tibia (*inches*)	9				9		9		9½	
Circumference of leg (*inches*).										
Lower border of patella	13½	13½							12¾	13½
2 inches below patella	12½	12¼			13		11¼		11¼	13½
4 inches below patella	13¼	12¾	12¼	13¼		14	9¾		10¼	14¾
6 inches below patella									9¼	13½
8 inches below patella	11¼	10½			10		9⅛		8	11½

Amputation of right leg November 30, 1942
Neurectomy: January 4, 1943.
Application of artificial limb April 4, 1943

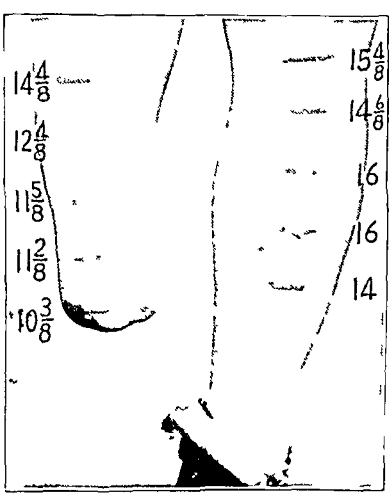

FIG. 3-A

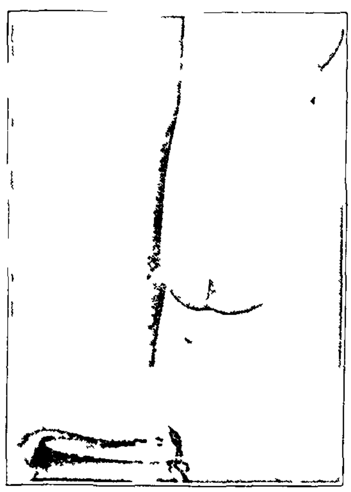

FIG. 3-B

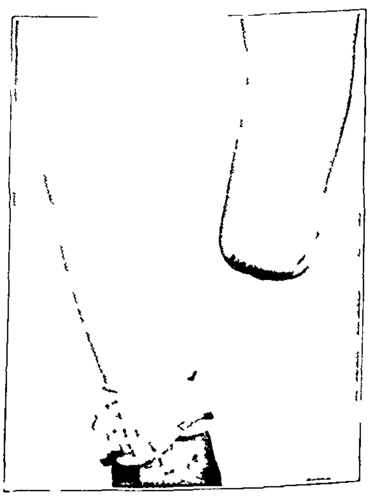

FIG. 3-C

Case 3. January 7, 1946.

TABLE III

Measurements in Case 3

	Mar. 25, 1943		June 9, 1943		Jan. 7, 1946	
	Right	Left	Right	Left	Right	Left
Length of tibia (*inches*)			9		9¼	
Circumference of leg (*inches*):						
At knee	16½	16½				
Lower border of patella					14½	15½
1½ inches below patella	13¾	14½	14⅛			
2 inches below patella					12½	14¾
3½ inches below patella	13¼	14¾				
4 inches below patella				15	11⅝	16
5 inches below patella	13½	15½				
6 inches below patella					11¼	16
7 inches below patella	12¾	15	11			
8 inches below patella					10⅜	14

Injury to right foot: December 16, 1941.
Amputation of right leg and neurectomy: March 29, 1943.
Application of artificial limb: June 30, 1943.

On January 15, 1946, this patient returned, wearing the same artificial limb with the addition of one sock on the stump. He was working on a cattle ranch and stated that he was able to do all the work that he had done before the loss of his leg. He was able to go hunting and to walk long distances over rough ground.

The amputation stump was conical in shape, and the operative scar in the popliteal space was soft (Figs. 1-A, 1-B, and 1-C).

Case 2. W. N. (No. 12,024) was a large white male, aged fifteen, and weighing 138 pounds. He was first seen on November 30, 1942, within a few minutes after he had sustained an extensive compound injury to the right foot. The leg was amputated; a stump, nine inches long, was left. The wound healed promptly, without infection.

On January 4, 1943, through an incision in the popliteal space, the muscular branches of the tibial nerve to the two heads of the gastrocnemius were sectioned. On April 10, 1943, an artificial limb was provided.

The final examination of this patient was made on December 22, 1945. He weighed 145 pounds, was walking without a limp, and had a painless stump. He was wearing the same artificial limb, provided four months and ten days after amputation, but was using two heavy socks. The stump was nine and one-half inches long and conical in shape (Figs. 2-A, 2-B, and 2-C), as shown by the measurements in Table II.

TABLE IV

Measurements in Case 4

	Sept. 2, 1944		Oct. 17, 1944		Dec. 1, 1944	
	Right	Left	Right	Left	Right	Left
Length of tibia (*inches*)					9	
Circumference of leg (*inches*):						
5 inches above patella	20¾	21	17¼	21	19	21
Center of patella	16½	16⅜	16	16⅜	15¾	16⅜
2 inches below patella	14½	14½	14¼	14¼	14⅛	14¼
4 inches below patella	14⅛	15⅛	14	15⅛	13⅝	15⅛
5½ inches below patella	14⅝	15⅞	13¾	15⅞	13¼	15⅞
7 inches below patella	14⅛	15¼	13¼	15¼	12⅛	15¼

Injury to right foot: August 12, 1941.
Amputation of right leg and neurectomy: September 18, 1944.

TABLE V

MEASUREMENTS IN CASE 5

	May 20, 1945		Dec. 20, 1945	
	Right	Left	Right	Left
Length of tibia (*inches*)				7
Circumference of leg (*inches*):				
Lower border of patella		14½	15½	14½
2 inches below patella		12¾	15½	13⅜
4 inches below patella		13½	15	13
6 inches below patella		12¼	13	11¼

Amputation of left leg and neurectomy: May 21, 1945.

CASE 3. R. S. (No. 12,472) was a large white male, aged thirty-nine, who weighed 195 pounds. He was first seen on March 25, 1943, with extensive involvement of the right foot, following a crushing injury received December 16, 1941.

On March 29, 1943, the right leg was amputated nine inches below the knee, and the muscular branches of the tibial nerve to the two heads of the gastrocnemius were sectioned. An artificial limb was applied on June 30, 1943, three months after operation, and two months later the patient started to work in an apple orchard.

The final examination was made January 7, 1946, at which time he was wearing the original artificial limb well; the stump was conical in shape and in good condition (Figs. 3-A, 3-B, and 3-C). He was able to go hunting, could walk as far as twenty miles, and was employed as an automobile mechanic.

CASE 4. J. B. (No. 14,606) was a very large, white male, aged forty-seven, who weighed 250 pounds. He was seen on September 2, 1944, with a marked deformity of the right foot as the result of injuries to the foot sustained August 12, 1941. On September 18, 1944, the right leg was amputated nine inches below the knee, and the muscular branches of the tibial nerve to the two heads of the gastrocnemius were sectioned.

Traction was applied to the stump for a short time; this was followed by the application of an elastic adhesive bandage. Three months after the operation, this patient was wearing an artificial limb very well.

Up to December 1945, the patient had not returned so that additional measurements could be taken, nor had he had another fitting of the artificial limb; but he reported that he was doing the work of a laborer, without discomfort.

CASE 5. Mrs. C. C. (No. 15,657) was a large white woman, aged fifty-four. She had a spastic paralysis, involving the left arm and leg, of twenty-seven years' duration. There was a severe equinovarus deformity of the left foot, and there had been an unsuccessful stabilization operation, ten years before.

On May 21, 1945, the left leg was amputated seven inches below the knee, and the nerve branches to the two heads of the gastrocnemius and to the soleus were divided through an incision in the popliteal space.

When last seen, seven months after operation, this patient had not been able to wear the artificial leg provided enough to bring about shrinkage of the stump. The shape of the stump was satisfactory, however, as is shown by the measurements in Table V.

THE MULTIPLE INNERVATION OF LIMB MUSCLES IN MAN * †

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INTRODUCTION

It is generally recognized that the majority of the muscles of the body have a plurisegmental innervation. It is also known that many of these muscles receive more than one nerve or nerve branch. The spinal segments giving rise to the nerve fibers to the individual muscles are given in all textbooks of anatomy, with some discrepancies in the respective accounts. Given less often are the number and location of the nerve branches to the individual muscles. Probably the most complete account of these details in current editions of English and American texts on gross anatomy is to be found in that by Morris.

Attention has been called to the practical importance of a knowledge of the number and location of these branches by the work of Markee and Löwenbach [2]. Working on the dog, these authors have shown that stimulation of different nerves or nerve branches to a given muscle may involve contraction of different "segments" along the length of that muscle. If only one of the several nerves to the rectus femoris—for instance, the proximal branch—be stimulated, contraction of the proximal portion of the muscle may be accompanied by an actual stretching of the middle and distal parts of the muscle, innervated by two other nerve branches. Observations on certain patients with partial paralysis of muscles indicate that the same phenomenon probably occurs also in the human. Weakness of a muscle, associated with displacement of its bulge upon contraction, as seen in certain patients after poliomyelitis, apparently is due to stretching of a part of the muscle, and consequently to unopposed contraction elsewhere.

In the dog, according to the results of Markee and Löwenbach [3], evidence indicates that, in at least certain long muscles, the fibers composing the different nerve branches to a muscle have arisen primarily from different spinal segments. In the rectus femoris, semitendinosus, and semimembranosus, if stimulation of a ventral nerve root has produced contraction in the proximal portion of the muscle, stimulation of a more caudal root produces contraction of a more distal portion of the muscle. Information on this latter point is not available for the human; but, with these possible applications in view, a study has been made of the number, location, and pattern of branching of the nerve supply to the long muscles of the limbs.

MATERIAL AND METHODS

The observations recorded here are based upon a careful and rather complete dissection of one cadaver, supplemented and extended by the use of routine dissecting-laboratory material. Because some of the nerve branches are frequently destroyed in a routine dissection, this latter type of material has been used to supply information only about branches absent in the more careful single dissection.

During the course of this special dissection, the nerves and muscles were demonstrated and moved in front of a motion-picture camera; thus the relations from a number of viewpoints were recorded. Photographic stills were then made from selected frames,

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 21, 1946.

† Aided by a grant from The National Foundation for Infantile Paralysis, Inc., New York, N. Y.

illustrating the innervation to each particular muscle. The drawings of the branchings to the various muscles were, in turn, made from these still photographs; and the precise relations of these nerves were again verified from the motion pictures. The figures of the nerves to the muscles we have chosen to present, therefore, depict rather exactly their location and manner of branching in one cadaver. While the authors are conscious of the variations which do occur from one individual to another, they believe this careful account of the nerve branching observed in one body will be in general more useful than a more schematized, and necessarily less exact, representation.

OBSERVATIONS

The data recorded here could logically be presented from any one of several aspects,—that is, from the standpoint of functional muscle groups, from that of anatomical location of the muscle, or from that of the nerves and their motor branches. We have chosen the latter aspect largely because of its simplicity.

The following description is derived from the dissection upon which the photographs and drawings are based. In parentheses are included data upon the nerve branching, abstracted from the texts of Cunningham and Morris. The source of the parenthetical material is indicated by *C.* for Cunningham, *M.* for Morris.

In the upper limb, the findings were as follows:

Musculocutaneous Nerve (Fig. 1)

Shortly before this nerve enters the coracobrachialis muscle, it gives off three branches to it (*M.*, one branch), two of which again branch, all entering the middle third of the muscle. As the nerve lies behind and between the two heads of the biceps, a single branch for both heads of the biceps is derived from the trunk (*M.*, one or two branches) and quickly divides into a nerve entering the upper third of each head; that for the long head divides into three branches before it enters the muscle. About three centimeters distally there arises a single branch (*M.*, one branch) for the brachialis. This divides into two branches, both of which enter the upper fourth of the muscle.

Median Nerve (Figs. 2, 3, and 4*)

The first muscular branches of this nerve supply the pronator teres (*M.*, one branch, dividing into one for each head), and arise just above the point at which the median nerve passes between the two heads of this muscle. The upper, shorter branch enters the proximal third of the humeral head of this muscle, dividing as it does so; a second branch gives off a twig to the upper third of the ulnar head and, passing distally between the heads, divides to enter the lower third of each head. As the median nerve passes between the two heads of the pronator teres, and before it passes deep to the flexor digitorum sublimis, it presents an ovoid enlargement from which several muscular branches arise. From the medial side arises the lower nerve to the pronator teres, already described; laterally arises a nerve which is distributed in part to the uppermost portion of the radial head of the flexor digitorum sublimis, the remainder passing through this muscle to enter the upper third of the palmaris longus (*M.*, one nerve). Slightly lower, from the lateral side of this swelling, arise two separate nerves for the flexor carpi radialis (*M.*, one nerve, dividing into several) which enter the upper fourth of the muscle about two centimeters apart. Immediately below the second nerve to the flexor carpi radialis there arises a second nerve to the flexor digitorum sublimis, which branches as it enters the upper part of the muscle only slightly distal to the first nerve to this muscle. A third nerve to the flexor digitorum sublimis arises from the median nerve as it courses behind the flexor digitorum sublimis. This branch enters at about the junction of the proximal and middle thirds of the muscle.

* Only the muscles whose innervation is illustrated in a given figure are labeled in that figure. es removed to show deeper structures may be identified by referring to preceding figures.

The interosseous branch of the median nerve carries the remaining motor fibers of this nerve, destined for the musculature of the forearm. From the interosseous nerve arise two branches to the radial head of the flexor digitorum profundus, the upper one branched (M., one or two branching). Arising close to the lower nerve to the flexor profundus is a

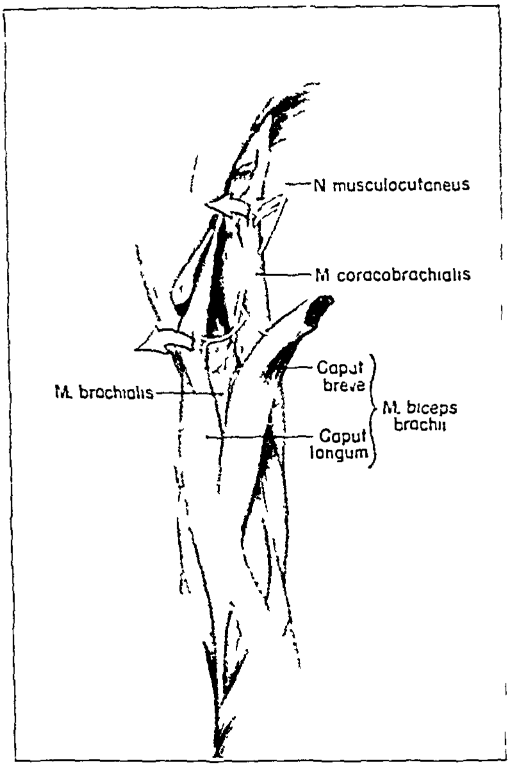

FIG 1

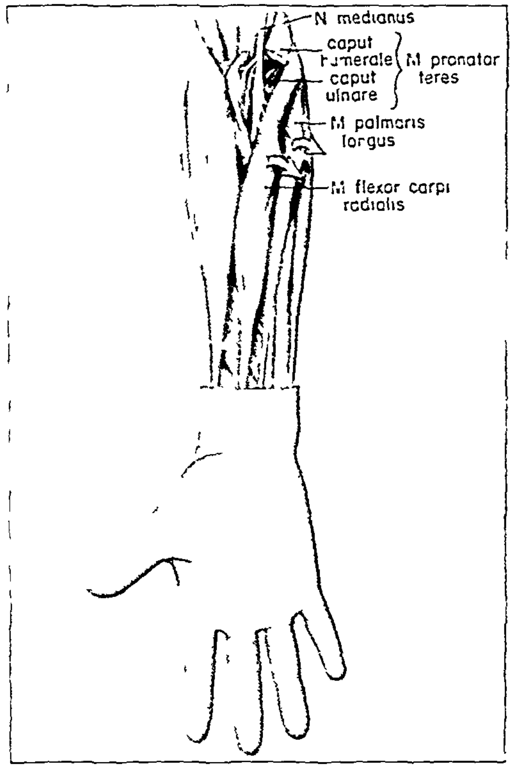

FIG. 2

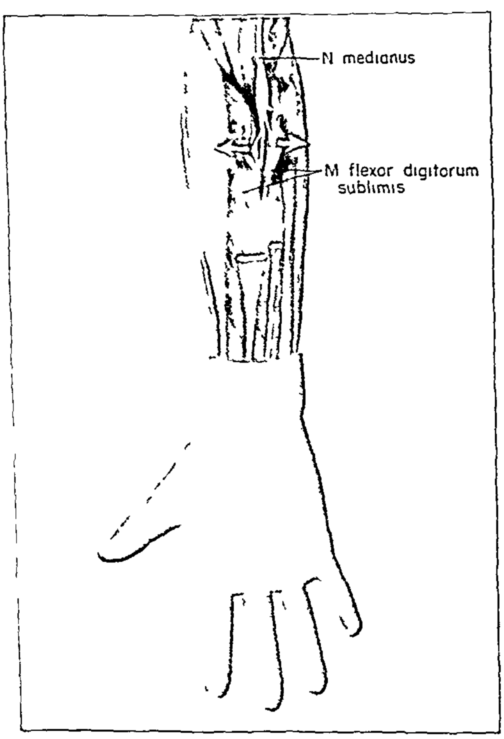

FIG. 3

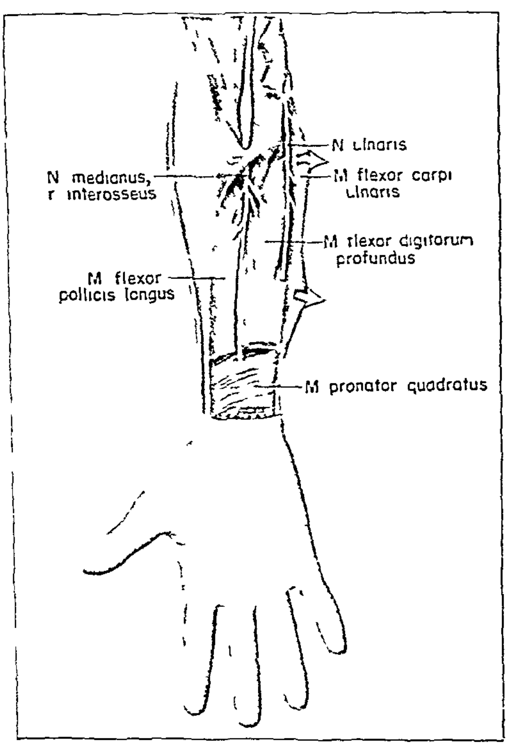

FIG. 4

branch to the upper part of the flexor pollicis longus. The interosseous nerve continues, much reduced, and gives off a second branch which enters the junction of the upper and middle thirds of the belly of the flexor pollicis longus (*M.* also describes two branches). The remaining motor fibers of the interosseus enter the deep surface of the pronator quadratus (*M.*, "branches").

Ulnar Nerve (Fig. 4)

As the ulnar nerve lies deep to the flexor carpi ulnaris, after passing between the two heads of origin of this muscle, it gives off a branch into the uppermost part of the muscle; a second branch arises just above the origin of the dorsal cutaneous branch, which in this case is quite high; a third branch to the flexor carpi ulnaris arises from the dorsal cutaneous branch, and enters the middle third of the muscle (*C.*, two to four; *M.*, two or three, or one branching). Arising from the ulnar nerve, between the first and second nerves to the flexor carpi ulnaris, is a single branch, dividing into two, entering the upper part of the ulnar head of the flexor digitorum profundus (*M.*, one branch).

Radial Nerve (Figs. 5, 6, 7, and 8)

As this nerve lies on the medial surface of the humerus, just before it enters the radial groove, it gives off its first muscular branch, to the long head of the triceps brachii (*M.*, one branch, dividing into several). Dividing into two, one of the subsidiary branches enters the long head at about the lower margin of the tendon of the teres major; the other courses farther along the posteromedial surface to enter the upper part of the middle third of the muscle.

A second muscular branch of the radial nerve, arising before this nerve disappears beneath the lateral head of the triceps, is distributed to the upper part of the lateral head. A third branch, arising just distal to this, goes to the medial head. It gives off one branch to the upper part of the medial head and then runs for a considerable distance along the medial surface of this head to enter the lower third of the muscle. Because of its course, this branch is frequently known as the ulnar collateral nerve. As the radial nerve passes between the origins of the medial and lateral heads of the triceps, on the posterior surface of the humerus, it gives off in succession a branch to the middle third of the lateral head, a stout branch into the upper lateral portion of the medial head, and a third branch entering the deep surface of the lateral head in the upper part of its lower third (*C.*, two branches to medial head; *M.*, "branches" to medial and lateral heads).

A branch from the radial nerve to the brachialis muscle was not found in this case. When such a branch occurs, it is probable, according to Cunningham, that it contains no motor fibers.

As the radial nerve lies between the brachioradialis and the brachialis muscles, it gives off a single nerve (*C.*, one or two; *M.*, one) to the former muscle. A short distance below this there arises a single nerve (*M.*, one or two nerves) to the extensor carpi radialis longus. From the point of division of the radial nerve into deep and superficial branches arises the nerve (*M.*, one nerve) to the extensor carpi radialis brevis, dividing into two, the lower branch entering about the middle of the muscle. The other nerves enter the upper third of their respective muscles.

Just before the deep radial nerve enters the supinator muscle, it gives off two branches to this muscle (*M.* mentions "branches"); in its course between the fibers of the muscle, it contributes three more twigs to it. As the deep radial nerve emerges from the lower border of the supinator, it fans out into a number of small branches. Two are given off in quick succession to about the junction of the upper and middle thirds of the extensor digitorum communis, and a single branch passes to the extensor carpi ulnaris (*M.*, one, branching into several). A third branch to the extensor digitorum communis (*M.*, one, branching into several, or two or three separate branches) and to the extensor digiti quinti

proprius passes more distally into those muscles. A branch also enters the upper part of the abductor pollicis longus (*M.*, one or more branches). The remainder of the deep radial nerve passes distally, giving off a branch into the uppermost portion of the extensor pollicis brevis (*M.*, one branch), another to the upper portion of the extensor pollicis longus, and

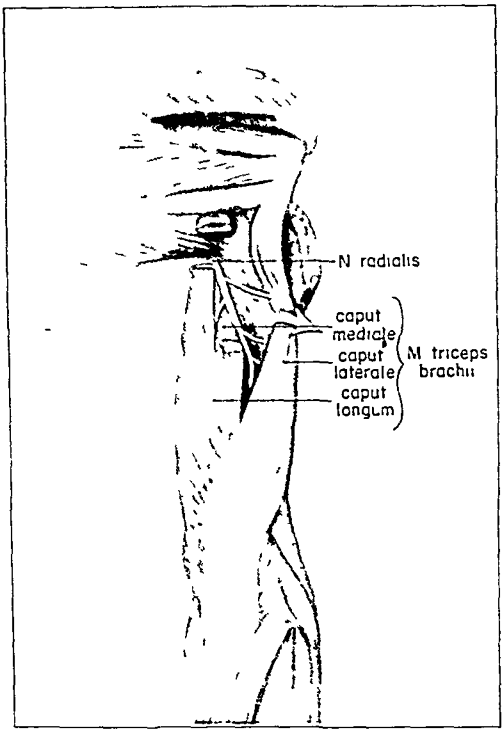

FIG 5

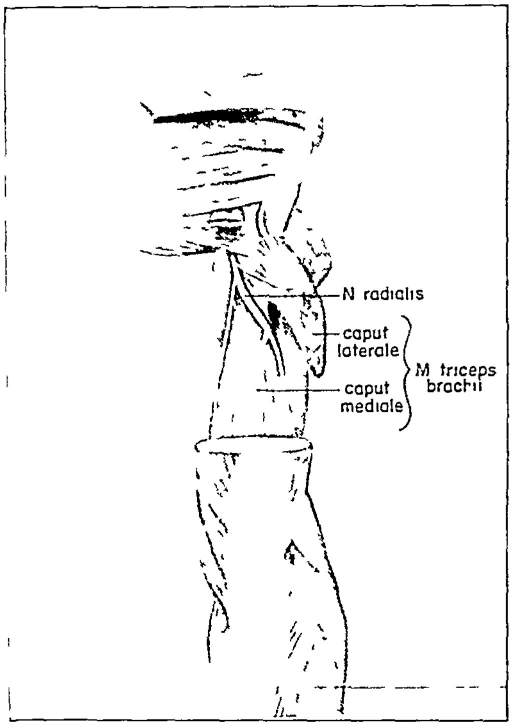

FIG. 6

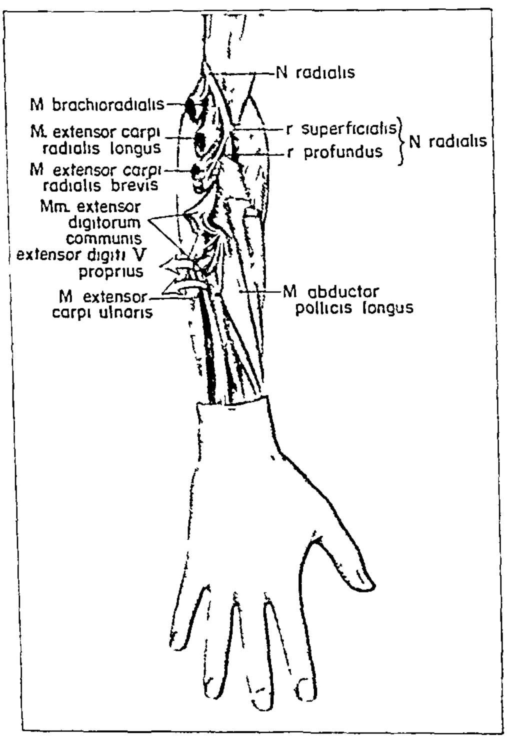

FIG 7

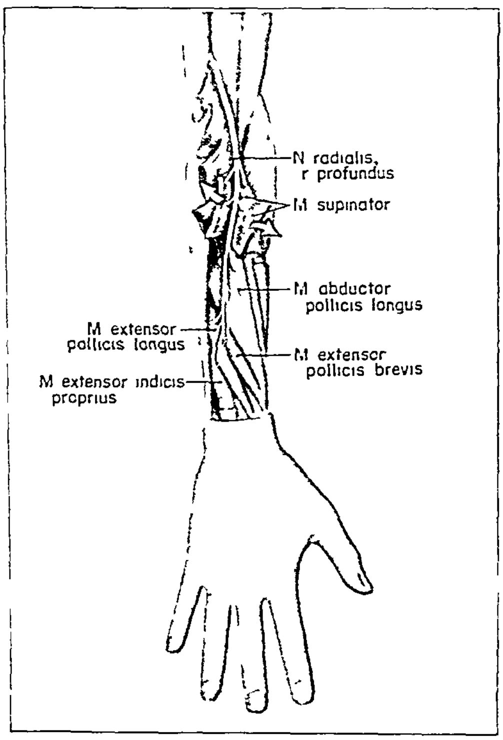

FIG 8

another to the upper third of the extensor indicis proprius (*M.*, one branch). Its final motor branch is a second twig to the extensor pollicis longus (*M.*, one, branching into several), into its upper third.

In the lower limb, the following observations were made:

Femoral Nerve (Figs. 9 and 10)

A short distance below the inguinal ligament, this nerve divides into a number of muscular and cutaneous branches. Among the first to be given off is the small nerve to the pectineus muscle (*C.* and *M.*, one or two), passing behind the femoral sheath into the upper third of the muscle. In addition to a cutaneous branch piercing the sartorius, two branches are given off to the upper third of this muscle (*C.*, two sets; *M.*, two). The upper branch divides once; the lower branch divides into several twigs, of which the lowest enters the muscle at about the junction of its upper and middle thirds. The nerves to the rectus femoris are also two in number (*M.*, two). The upper divides to enter the upper third of the muscle; the lower in turn again divides, giving two twigs into this part of the muscle and continuing to enter the middle of the belly of the muscle. A single nerve to the vastus medialis (*C.*, two nerves; *M.*, one, branching) runs upon the medial surface of the muscle in the adductor canal; it gives off twigs into the upper part of the muscle, and continues its course to penetrate the muscle at about its middle. A single nerve to the vastus lateralis (*M.*, three nerves) divides before entering the distal part of the upper fourth of the muscle. The vastus intermedius receives a single nerve, entering the upper part of the muscle (*C.* and *M.* also mention an innervation from the nerve to the medialis, the lateralis, or both). The nerve to the articularis genu (not illustrated) is derived from the nerve to the vastus intermedius.

Obturator Nerve (Figs. 11 and 12)

As this nerve emerges from the obturator foramen, under cover of the pectineus muscle, it divides into anterior and posterior branches. The anterior branch gives off a single twig into the posterior surface of the upper margin of the adductor brevis (*M.* mentions "rami"), and then crosses superficially to this muscle. It gives off a single branch, which divides into three as it enters the junction of the upper and middle thirds of the adductor longus (*M.*, one branch, giving off several twigs; occasionally there is a second branch, probably sensory, from the femoral nerve). The remaining muscular branch of this nerve divides into three twigs, which enter the lower part of the upper third of the gracilis (*M.*, one branch).

The posterior branch of the obturator nerve passes deep to the adductor brevis, to end in four branches (*M.*, one or more) which penetrate the upper third of the adductor magnus.

Sciatic Nerve (Figs. 13 and 14)

Just below the ischial tuberosity, the sciatic nerve gives off the upper of the two nerves to the semitendinosus (*C.*, two; *M.*, two, each may be doubled). This upper nerve quickly divides into three short branches, which enter the muscle close together, about four centimeters below the tuberosity. The sciatic nerve then gives off a single branch to the long head of the biceps femoris (*M.*, two: one or both doubled, or both combined) which enters the muscle high. The upper of the two nerves to the semimembranosus (*M.*, "several" nerves) enters the deep surface of that muscle in two branches, which penetrate the muscle just below its tendon of origin, therefore close to the middle of the thigh. A further branch of this nerve passes downward on the posterior surface of the adductor magnus, sending three branches into the lower half of this muscle (*M.*, one branch).

The second nerve to the semitendinosus arises about four centimeters lower, passing unbranched into the deep surface of the muscle at about the junction of the middle and lower thirds. About four centimeters below this, the second nerve to the semimembranosus

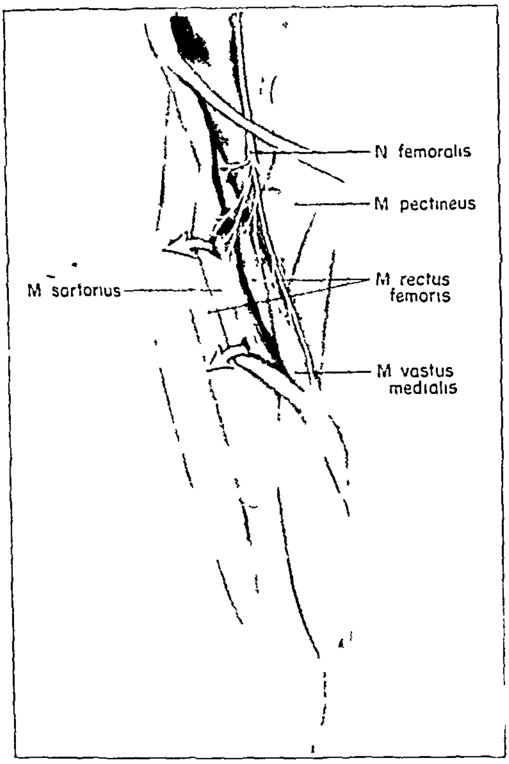

FIG 9

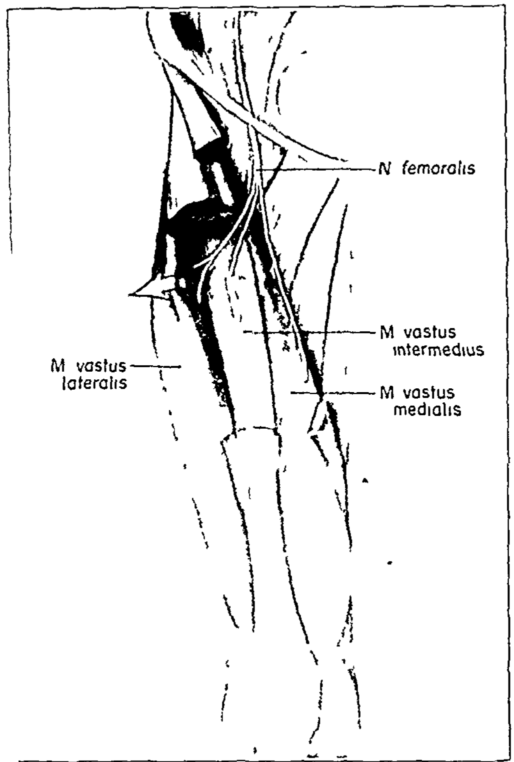

FIG 10

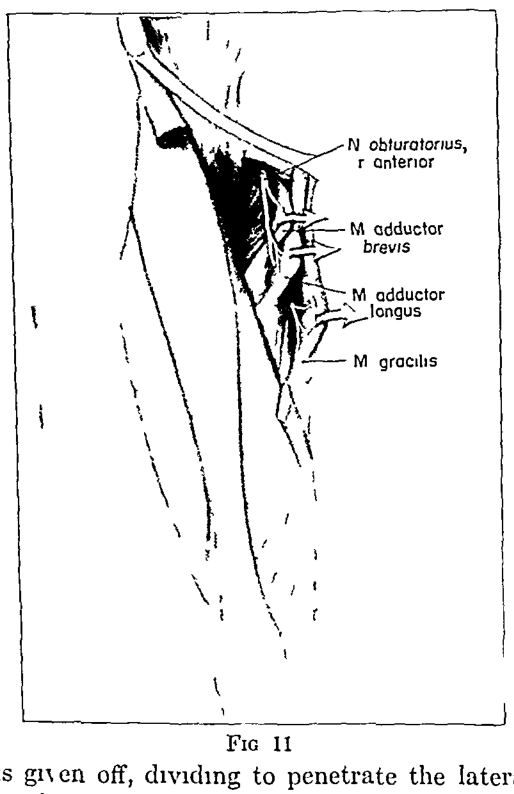

FIG 11

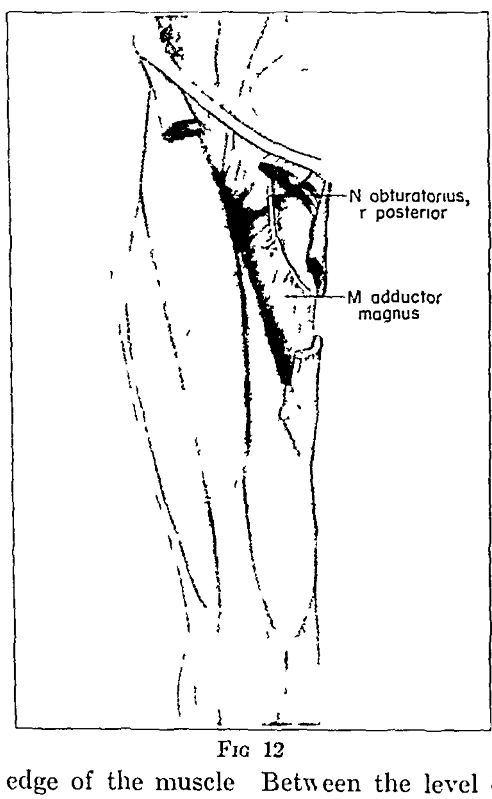

FIG 12

is given off, dividing to penetrate the lateral edge of the muscle Between the level of origin of these two latter nerves there arises, from the peroneal side of the sciatic nerve, the single nerve to the short head of the biceps (M, one nerve), which branches once as it enters the upper part of the fleshy origin of this muscle

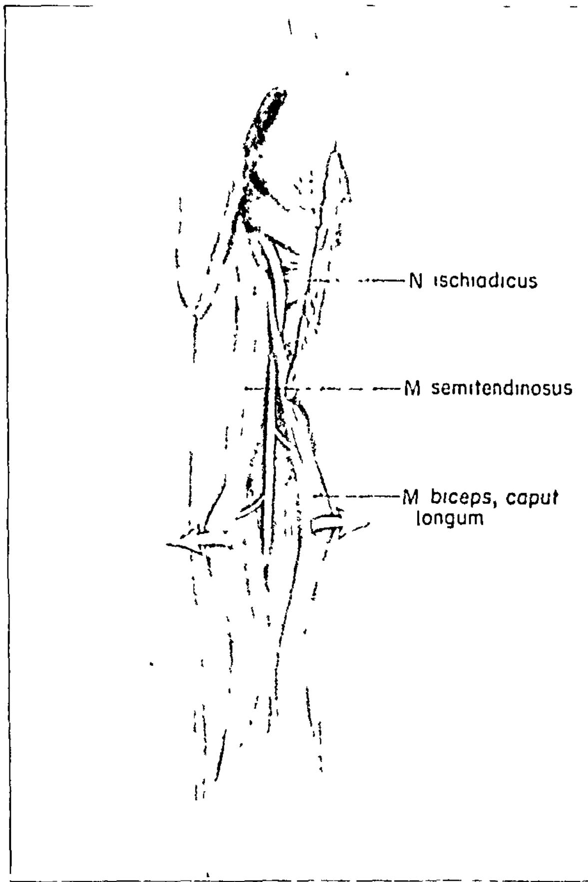

FIG. 13

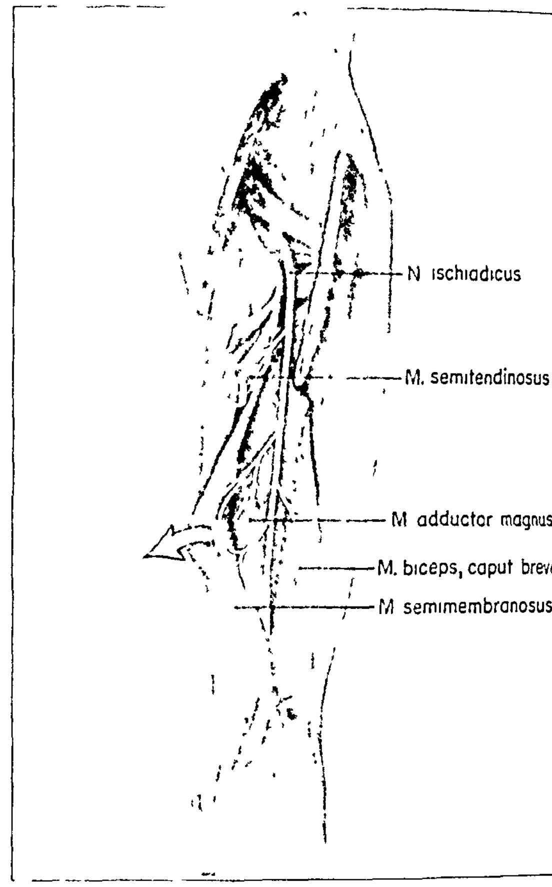

FIG. 14

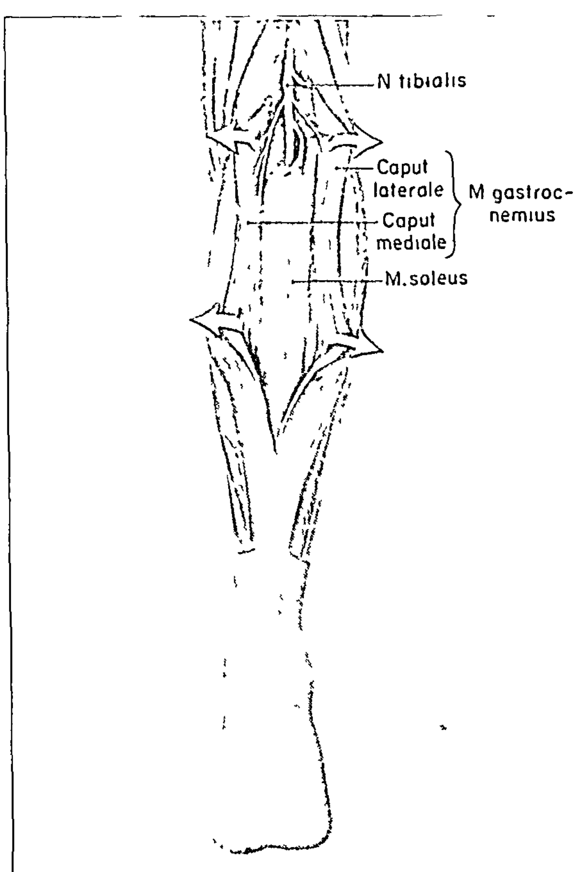

FIG. 15

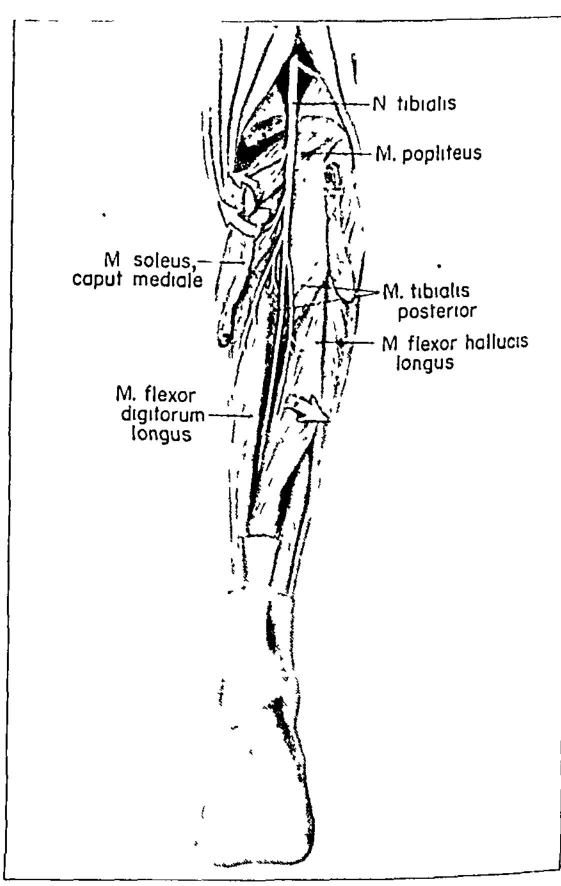

FIG. 16

Tibial Nerve (Figs. 15 and 16)

Shortly after its origin from the sciatic nerve in the popliteal fossa, the tibial nerve gives off from its anterior surface a twig (not illustrated) to the plantaris muscle (*M.*, one) and then gives off medial and lateral muscular branches, one to each head of the gastroc-

nemius (*M.*, one branch for each head). These nerves enter the heads of this muscle close to their origins; that for the medial head divides into three twigs just before it disappears in the muscle, that for the lateral head into two. Just below the origins of these nerves there arises, from the posterior surface of the tibial nerve, a single nerve which divides to supply one nerve to each head of the soleus muscle (*M.*, one nerve dividing into one for each head; also branches from the tibial nerve into the deep part of the muscle). As it lies deep to the soleus, the tibial nerve gives rise to a second branch to the medial head. This enters the muscle in two twigs.

The nerve to the popliteus (*M.*, one nerve, sometimes two) arises about the middle of this muscle, therefore above the origin of the second nerve to the soleus, and runs across the superficial surface of the popliteus to wind around its lower border and penetrate its deep surface. At the lower border of this muscle, the nerve to the flexor digitorum longus arises in common with that to the tibialis posterior. That for the posterior tibial muscle quickly separates from that to the flexor digitorum longus, and divides to enter the upper part of the muscle (*M.*, one nerve, branching). The nerve to the flexor digitorum longus (*M.*, one dividing into two: one for the medial, one for the lateral part of the muscle) also divides early, one branch entering the upper part of the muscle; the second longer branch runs for some distance upon the surface of the muscle, giving branches into it, and finally disappears into about the middle of its muscle belly.

The nerve to the flexor hallucis longus (*M.*, one or two nerves) arises shortly below the first nerve mentioned. It gives two branches into the upper part of the muscle, and a third branch runs downward on the deep surface of the muscle to disappear into its substance about the middle of its belly.

Peroneal Nerve (Figs. 17 and 18)

The superficial peroneal nerve gives off a branch to the upper part of the peroneus longus (*M.*, two) just before it passes between this muscle and the bone. As it attains the anterior side of the leg, it gives off its second muscular branch, a long slender one which

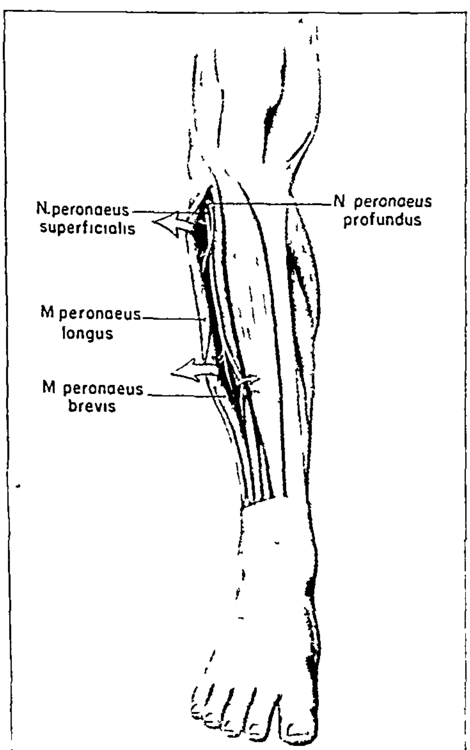

Fig. 17

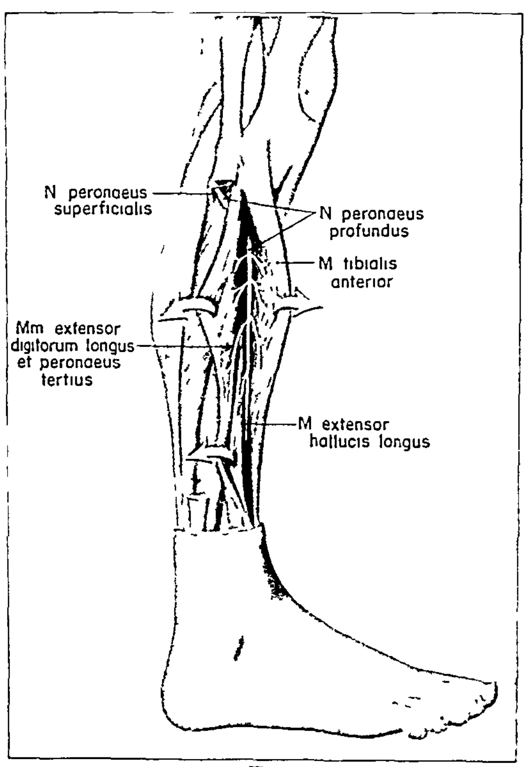

Fig. 18

runs down to the peroneus brevis (*M.*, one branch), giving several branches into the upper part of the muscle and then running along its surface to disappear in its middle third.

Under cover of the peroneus longus, the deep peroneal nerve also gives a branch into the upper part of this muscle, this branch dividing as it enters. The deep peroneal then gives off a number of separate branches to the extensor digitorum longus and to the tibialis anterior. Those to the extensor digitorum longus are three in number (*M.*, two branches). The upper two arise close together, and branch once each as they enter the upper third of the muscle; the third nerve to this muscle, arising somewhat lower, gives a branch into the middle third of the belly, and runs along the deep surface almost to the tendon before disappearing in the muscular substance. The lower nerve to the extensor longus also supplies the peroneus tertius (*M.*, one). There are also three nerves to the tibialis anterior (*M.*, one with several twigs from common peroneal nerve, one from deep peroneal nerve). The upper two enter the upper third of the muscle, both branching before entering; the lower nerve gives a branch into the middle third, and runs some distance before finally disappearing into the lower third of the muscle.

A single nerve into the upper third of the extensor hallucis longus (*M.*, one nerve), branching as it enters, completes the muscular branches of the peroneal nerves in the leg.

DISCUSSION

Of the fifty-eight separate heads of origin of the long muscles of the limbs which we have considered here, all but fifteen were penetrated by nerve branches at more than one point. This was true of the one body described and illustrated here; ten of these fifteen are known to receive more than one nerve branch in other individuals.

Included in the cases of muscles receiving more than one nerve branch are both those to which two or more nerves arise separately from the main nerve trunk, and those to which the two or more entering nerves are derived from a single stem. These two apparently different conditions are in reality only the result of varying types of fasciculation, for in some bodies the nerves arise separately, while in others they are bound together in a common sheath of connective tissue.

Many of the longer muscles receive their nerve supply at two rather distinct levels, one nerve branch penetrating the muscle close to its origin, other branches entering the middle or, rarely, the distal third. This anatomical pattern is similar to that in the dog, in which experiments on certain muscles have shown that the nerves entering at different levels control different "segments" along the length of the muscle. If experimental data are to be obtained in the human by nerve stimulation, this pattern of branching suggests the muscles upon which such observations might most fruitfully be made.

However, it should be pointed out that the manner and position of entrance of the nerves to a muscle give little evidence of the distribution of these nerves within the muscle. In the case of the adductor magnus, it would seem fairly obvious that the obturator nerve controls, in general, a proximal part of the muscle, and the sciatic nerve, in general, a distal part. A different type of distribution is illustrated by the nerve supply to the flexor digitorum profundus; it is well known, both anatomically and clinically, that an ulnar portion of this muscle is supplied by the ulnar nerve, a radial portion by the medial nerve. For most muscles, even such apparently simple conclusions cannot be reached from observation of anatomical material. In the rectus femoris of the dog, for instance, the three nerves entering the muscle do control upper, middle, and lower "segments" of this muscle; however, these segments are roughly triangular in shape, the upper and lower segments nearly meeting each other. Moreover, judging by the results of stimulation in the dog, the extent of a muscle controlled by a given nerve branch bears no precise relation to the relative size of this entering branch. Perhaps this may be due to variations in the number of sensory fibers included in the various nerves.

Many of the muscles, although they receive several branches, receive these very close

together, and thus the external pattern of branching gives no evidence whatever of their distribution within the muscle. One can also only speculate concerning the functional distribution of the nerve fibers to those ten muscles in this body which we found to receive only a single unbranched nerve, but which in other bodies may receive more than one branch.

The existence of multiple nerve branches in the human, and the fact that in the dog different parts of the muscle contract on stimulation of different ventral spinal roots, might at first thought be interpreted to mean that the different branches supply regions of the muscle developed from different somites. It should be remembered, however, that neither experimental embryological evidence nor observations on the developing human embryo support the hypothesis that the limb muscles are derived from somites; the experimental evidence in the *Amphibia*, for instance, indicates clearly that the limb muscles in these forms are derived from unsegmented lateral mesoderm. The segmental innervation of the limb as a whole is of course evident; however, the relations between the developing nervous and muscular systems are certainly as yet not fully understood, and further discussion of the known facts would be out of place in this paper.

It might also be pointed out that the number of nerve branches entering a muscle bears no fixed relation to the number of spinal-cord segments which are said to innervate that muscle. The individual muscles of the limbs are regularly supplied through from two to four spinal nerve roots; the variations given for any one muscle by different authors may reflect real variations between individuals, the paucity of our knowledge, or both. There is not the slightest evidence that the variations in the nerve branching to a muscle are correlated with the segmental nerve supply to that muscle.

It would be tempting to try to correlate the observations presented here with various clinical conditions. Yet, as the data presented here are based upon experiments on the dog and observations on the human cadaver, any speculation concerning their clinical significance would seem at this time to be premature.

SUMMARY

Experimental evidence from the dog, demonstrating the physiological importance of the multiple innervation to individual muscles, led to the detailed observations, here presented, upon multiple nerve branches in the human. Of fifty-eight separate heads of origin of the long muscles of the limbs in one cadaver, all but fifteen were entered by nerve branches at more than one point. Ten of these fifteen are known to receive more than one branch in other individuals. These multiple branches may enter the muscle close together, or may be distributed for some distance over the length of the muscle. In neither pattern of branching can the ultimate distribution of the nerve fibers within the muscle be deduced from a purely morphological study.

The evidence obtained from experiments on the dog by Markee and Löwenbach demonstrates that the multiple nerves entering a muscle may control the contraction of different "segments" along the length of the muscle. The present study has emphasized that a similar anatomical condition exists in the human. However, physiological evidence similar to that for the dog has yet to be obtained.

NOTE It is a pleasure to express our indebtedness to Mr Elon Clark and his co-workers in the Division of Medical Illustration for their artistic and accurate drawings

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ACTIVE SPLINTING OF THE HAND *

BY STERLING BUNNELL, M.D., SAN FRANCISCO, CALIFORNIA

Hands are peculiar in that they are prone to become stiffened,—evidently because the joint surfaces are so accurately approximated, and there are more close-fitting, gliding parts than elsewhere in the body. Joint ligaments are just long enough, but not too long. If, from any cause, a hand remains swollen and immobile, the serum-soaked ligaments become short and thick, binding the joints. From the fluid of oedema, fibrin settles between the movable tissues and within them,—muscles, tendons, and joints alike. Fibroblasts invade; the whole becomes organized and shrinks; and the hand becomes congealed. The proximal joints of the fingers stiffen in the straight position, because of their collateral ligaments. These ligaments are tight in flexion, but shorten when they are relaxed, with the joint in the straight position, in such a way that they prevent flexion.

FIG. 1

Cock-up splints of flat spring steel or piano wire, used to dorsiflex wrist and furnish exercise. Upper view shows wrist in dorsiflexion; lower view, in flexion.

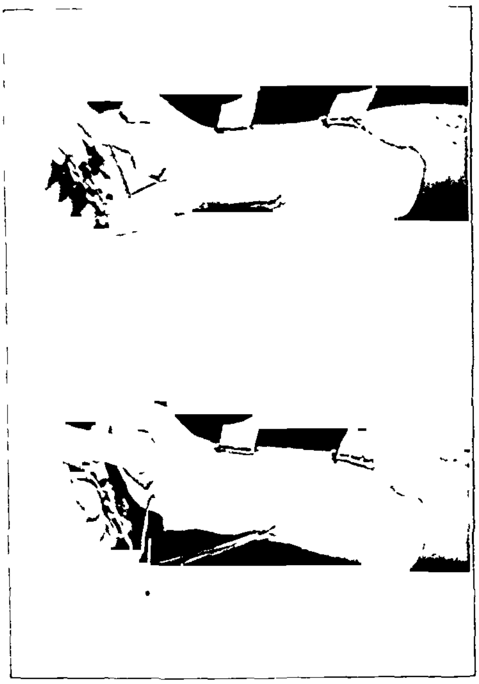
Splints cause stiffness of the hands if they extend beyond the distal crease in the palm to include the digits, if they are kept on too long, if they hold a joint in a rigid, strained position, or if they hold the hand in a position of non-function. Errors of position in splinting are to hold the wrist flexed, the fingers straight, the palm flat, and the thumb at the side of the hand or pressed close into it.

The wrist is the key joint to the position of function. When held flexed, in the protective position assumed by a sick hand, the extensors of the digits are tightened, hyperextending the proximal joints of the fingers, drawing the thumb back and to the side of the hand, flattening the metacarpal arch, and secondarily, from the flexors, producing clawing of the fingers. The intrinsic muscles are then too far off center to act. Shortening of the muscles from disuse exaggerates the effect. The muscles are in balance in this position of non-function; but, if we dorsiflex the wrist, they will be in balance in the position of function. The position assumed by the hand is determined by muscle balance, which changes with the position of the wrist. In examining many patients who were brought from overseas with their hands in plaster, it was rare to find a dorsiflexed wrist.

The injured hands which were found to be limber were those in which the wounds had been closed quickly; in which only the injured part of the hand had been immobilized, and for but a short time; in which the position of function had been maintained, especially with the proximal joints in flexion; and in which movement had been active and continuous.

Splints which are used to immobilize inflamed or healing parts—such as occur with osteomyelitis, fractures, or after plastic surgery—must of necessity be stationary. In this paper a system is outlined of using elastic splinting or spring splinting to coax joints around

* Presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1946.



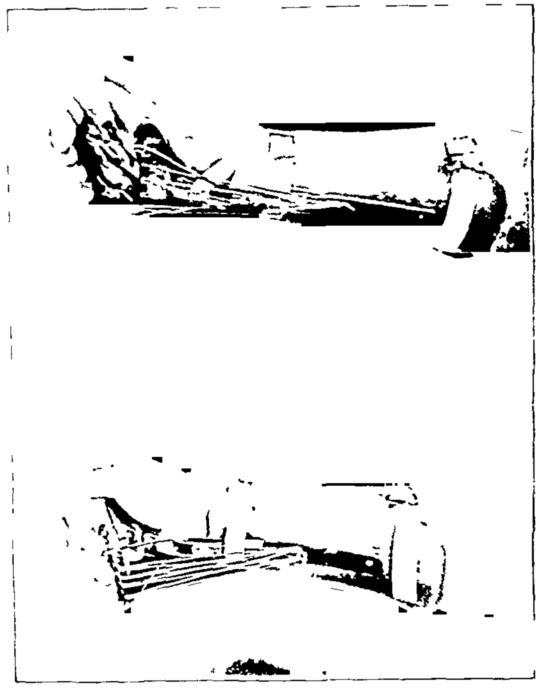


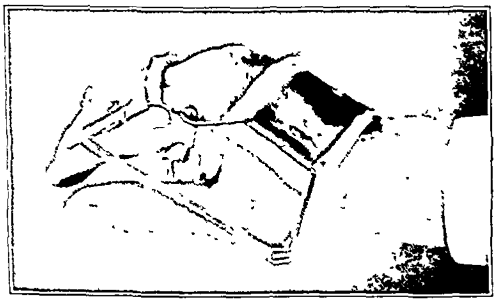
FIG. 2　　FIG. 3

Fig. 2: Splint to flex and exercise proximal joints of fingers. Direction of pull of rubbers is adjusted by bending outrigger.

Fig. 3: Metal spring splint with outrigger, over which has been slipped metal tubing to act as a roller, bent to give the desired direction of pull of the rubbers. Upper view shows dorsiflexion of wrist and extension of proximal joints of fingers. Lower view shows flexion of wrist and of proximal finger joints.

from the position of non-function into that of function, and to maintain them so. Spring splints are also advised as a substitute for paralyzed muscles in peripheral-nerve injuries.

In forcing joints into other positions, spring or elastic splinting has been found to be more efficient than unyielding splinting. Rigid splinting makes rigid hands. In splinting with springs or elastics, the joints are never strained to excess, nor are they immobilized. Active splinting is physiological splinting. Hands need mobility to thrive. If kept still, they become atrophied and stiff. The hands work continuously against the springs or elastics; and, with these splints, they are actually exercised. By this system we splint to



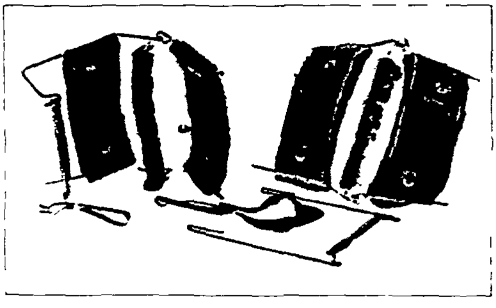


FIG. 4　　FIG. 5

Fig. 4: Illustrates knuckle-bender splint, which has been designed to flex and exercise proximal joints of fingers. The splint has three padded points of pressure, activated by rubber bands and with pivots corresponding to the axes of the joints. Motion is carried through the full range. Rubber on back of the thumb helps to oppose it.

Fig. 5: Shows knuckle-bender splint, with leather loop and rubber to draw the thumb into opposition. Note the outrigger with tube roller, over which leather loops and rubber bands draw the fingers into extension in the correction of claw-hand.

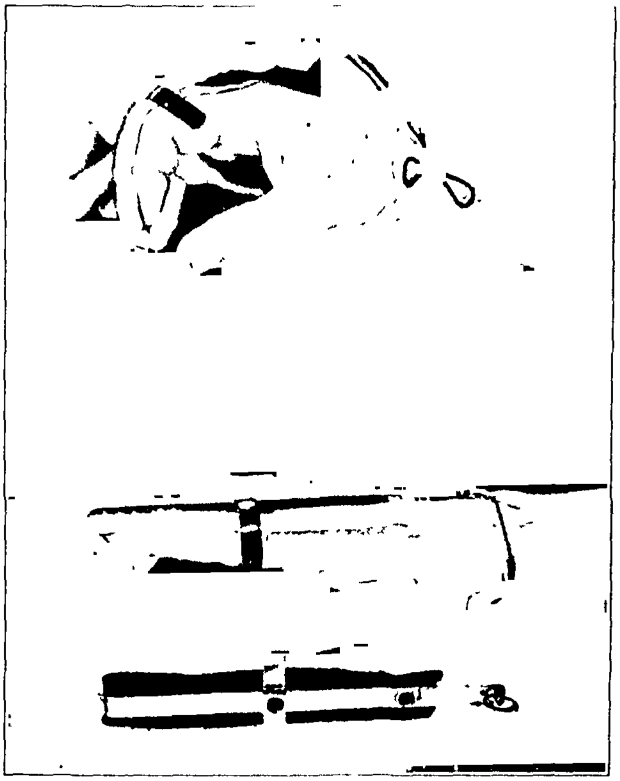
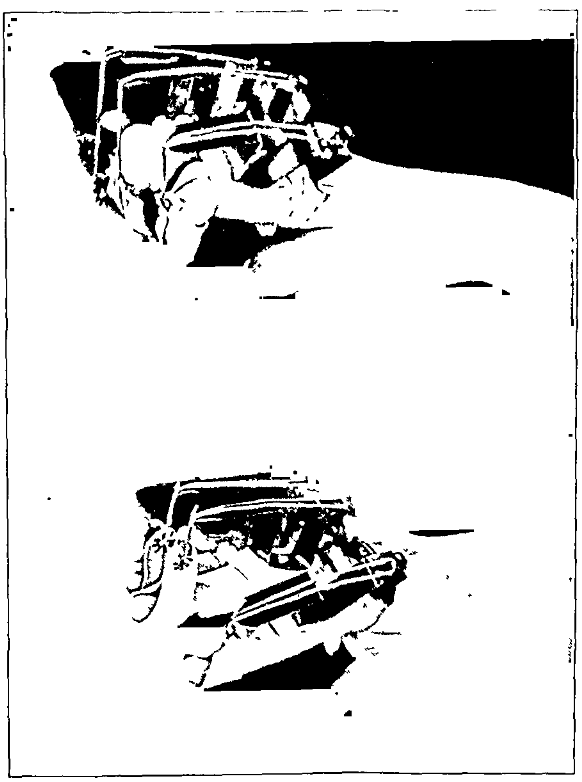


FIG. 6

FIG. 7

Fig. 6: Simple splint of clock spring, to draw fingers into extension. The range of motion is demonstrated.

Fig. 7: Safety-pin splint of spring wire (0.033 inch) to straighten finger. The two views show the spring motion.



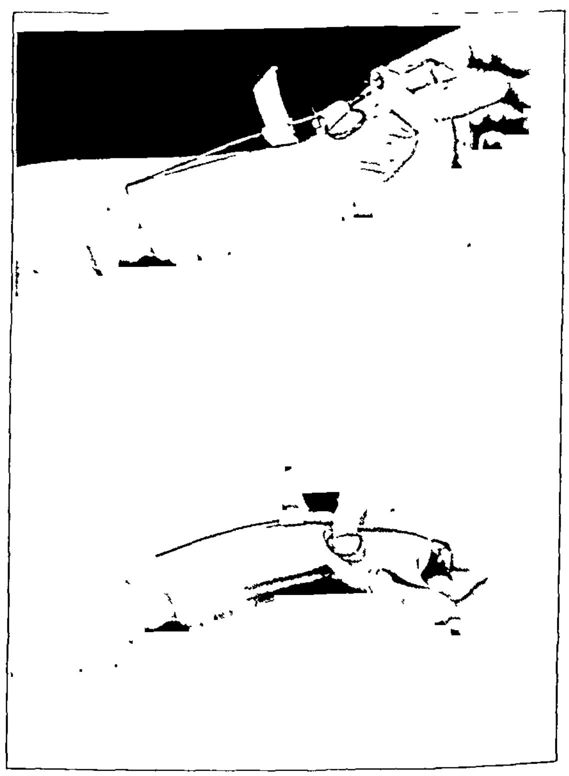


FIG. 8

FIG. 9

Fig. 8: Splint of clock spring, designed to extend and exercise the fingers (developed at Dibble General Hospital).

Fig. 9: Modified Oppenheimer splint, used to balance the muscles in cases of radial palsy. The main spring wires are light (0.069 inch). The thumb is held by a leather loop and light spring wire (0.033 inch) instead of a rigid ring, so as to give free mobility. Strap passes through wire rings to retain splint in place. Upper and lower views show motion possible.

mobilize, not to immobilize. It is functional splinting. The muscles pump away their stagnant fluids, washing out the toxins; the tendons keep gliding and the joints keep moving, thus preventing adhesions and keeping these structures normal.

In active splinting, the splints should be light, and should not interfere with occupational therapy or other work. They force the joints around into the position of function,—that is, the wrist into dorsiflexion, the proximal joints of the fingers into flexion, the palmar arch into a curve, and the thumb into the position of opposition. Also, the splints extend clawed fingers. In the position of non-function a little motion is useless; but in the position of function, motion is useful for pinching and for picking up objects. When a hand can do this, it will be used more and more, and will continually improve with work.

SPLINTING FOR PARALYSIS

Paralytic patients have been oversplinted. The dictum formerly was to keep the paralyzed muscles fully relaxed by splinting unremittingly in the position opposite to that of the deformity. So many hands have been crippled from overcorrection and stiffened from rigid splinting that some neurosurgeons have rejected all splinting in cases of paralysis. This is going too far in the other direction. Without splinting, the paralyzed muscle becomes too long. The deformity from muscle imbalance eventually becomes fixed. Then, after the nerve recovers and reinnervates the muscle, it has the additional task of shortening the muscle against deformity and against the pull of a strong antagonist. It is unnecessary to keep the paralyzed muscle in full relaxation; merely to keep it in the position of function is sufficient. No splinting is needed, except for the specific muscles involved; all other parts of the hand should be free for activity. The object should be to supply a spring or elastic pull, of just sufficient degree to serve as a substitute for the paralyzed muscle, to maintain muscle balance in the position of function. The splint should be as light as pos-

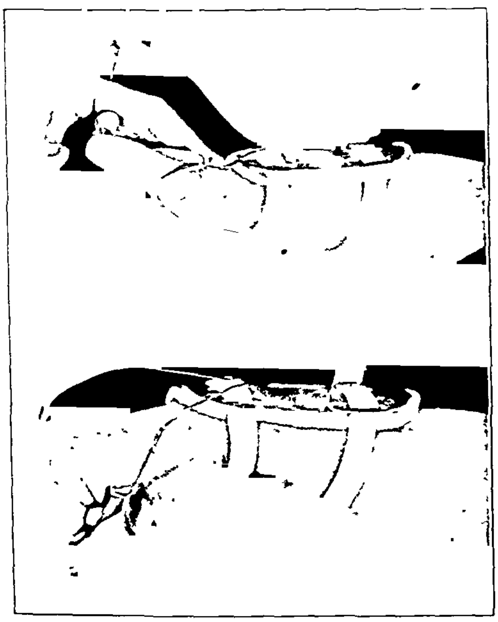


FIG. 10

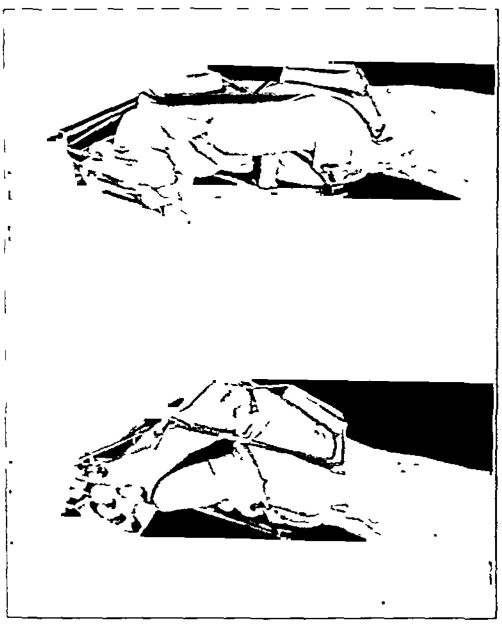


FIG. 11

Fig. 10: Suspension splint for radial palsy (Thomas) to furnish muscle balance and complete freedom of action for manual work. The spring wire which holds the thumb is very light. Degree of motion is demonstrated.

Fig. 11: Knuckle bender, used in palsy of both median and ulnar nerves to correct muscle balance by substituting for paralyzed intrinsic muscles. Upper view shows position of claw-hand, with thumb at the side and proximal finger joints straight. In lower view, position has been corrected by elastic pull of rubber bands, straightening clawed fingers, flexing proximal joints of the fingers, drawing the thumb into opposition, and curving the metacarpal arch. Outrigger with tubing roller has been snapped into place.

sible, and should allow free, unhampered use of the hand for manual work. Such a spring splint exercises all of the muscles. For radial palsy, if a man keeps his hand always in supination, the extensor muscles will be protected by gravity, making splinting unnecessary; but the patient will not always maintain this position and, without supination, his hand will not fall into dorsiflexion.

The principle of active splinting, although developed for the hand, is applicable to other joints. For example, after the acute phase has passed in poliomyelitis, we need just enough spring substitution to complete the muscle balance and still allow free exercise of the limb.

DISCUSSION

DR. PHILIP D. WILSON, NEW YORK, N. Y.: This system of splinting which Dr. Bunnell has demonstrated is extremely ingenious. It is the result of many years of thought and study. Many of us cannot even understand the full implication of some of these splints and what they do. Because Dr. Bunnell has worked through the various main centers of the Army, he has been able to multiply his own efforts so that relief has been brought to many hundreds of men with crippled hands. I visited one of these centers, and was greatly impressed by the work there. I am very sorry that General Kirk is not here to discuss this paper and to express the gratitude which we all feel toward Dr. Bunnell.

A STUDY OF SUPINATION AND PRONATION, WITH ESPECIAL REFERENCE TO THE TREATMENT OF FOREARM FRACTURES *

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From the Orthopaedic Department, Glasgow Royal Infirmary

This study is based on a series of about 6,000 fractures of the forearm treated during the last eleven years, and on a small number of non-traumatic cases with limitation of rotation due to other causes. Only a portion of the fracture cases had more than slight limitation of rotation; 1,245 such cases were especially investigated and followed up, and these formed the major part of this work.

Rotation is the movement mainly affected after union of forearm fractures, and yet this important function is very often neglected in the treatment of these cases. Good pronation is necessary in eating with a knife and fork, in typing, and even in as fundamental an action as picking up a small object. Full supination is needed for such everyday actions as accepting one's change in the bus or wielding a shovel. Different patients have their own peculiar complaints associated with loss of supination; a violinist will find it impossible to play if his left forearm is affected, and a farmer's wife will explain how difficult it is to milk a cow. It is possible to compensate partly for loss of pronation by abducting the humerus, but limitation of supination does not admit of ready compensation by any such manoeuvre.

Observations of normal people reveal marked individual variations in the range of supination and pronation, even though the range in both forearms of any single individual is identical. The range of rotation seems to decrease with age. Pronation shows the greater individual variation, and in normal adults its range may be as little as 30 degrees. Supination, on the other hand, is rarely less than 70 degrees.

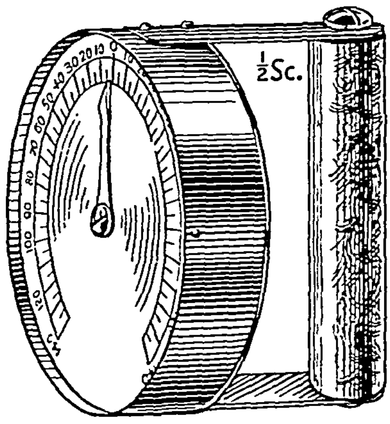


FIG. 1

Goniometer for measurement of supination and pronation. (*Reproduced by permission from the British Medical Journal, Aug. 19, 1944.*)

CLINICAL MEASUREMENT OF SUPINATION AND PRONATION

In order to make comparative clinical measurements of supination and pronation, a special goniometer was devised (Fig. 1). The pointer of the instrument is fastened to a spindle, running through the axis of the drum; a weighted lever, fixed on the spindle inside the drum in a position diametrically opposite the pointer, keeps the pointer vertical as the drum with the scale rotates. Zero position is taken when the handle of the instrument, which the patient grasps, is vertical and in line with the humerus.

Direct measurements of the range of supination and pronation are valueless for comparative purposes, since the range of rotation may vary enormously in different individuals. One must always read the range of supination and pronation on right and left arms and record the limitations of supination and pronation as minus x and minus y degrees, respectively. In pronation, the patient tends to abduct the elbow and so to falsify the reading; this error must be guarded against. In supination, the patient may lean toward the injured side; and, to get an accurate reading, this error must also be checked.

* Based on a paper given at a meeting of The British Orthopaedic Association in Glasgow, June 1943, and on a Hunterian Lecture delivered at the Royal College of Surgeons of England, at London, May 31, 1945.

THE MECHANICS OF SUPINATION AND PRONATION

The movement of the radius around the ulna is like that of the handle of a bucket. The head of the radius pivots in the annular ligament, while the lower end swings around the head of the ulna, being attached to it by the articular disc.

The fibers of the *interosseous membrane* run downward from the radius to the ulna. During pronation of the forearm, the radius moves downward slightly in relation to the ulna, so that the fibers of the interosseous membrane tend to be slack.

The *axis of rotation* of the radius passes through the center of the head of the radius at the upper end; at the lower end it passes through the head of the ulna at a point close to the base of the ulnar styloid. When this axis is drawn on an anteroposterior roentgenogram of the forearm bones, it is found to pass exactly along the interosseous border of the ulna (Fig. 2). In a lateral roentgenogram, the interosseous ridge of the ulna is usually found to lie slightly behind the axis of rotation. The sectional relation of the axis of rotation to the interosseous border of the ulna is shown in Figure 3. It will be seen from this diagram that the fibers of the interosseous membrane tend to become tightened during pronation and slackened during supination. This effect, due to the axis of rotation lying in front of the interosseous membrane of the ulna, is exactly balanced by the opposite

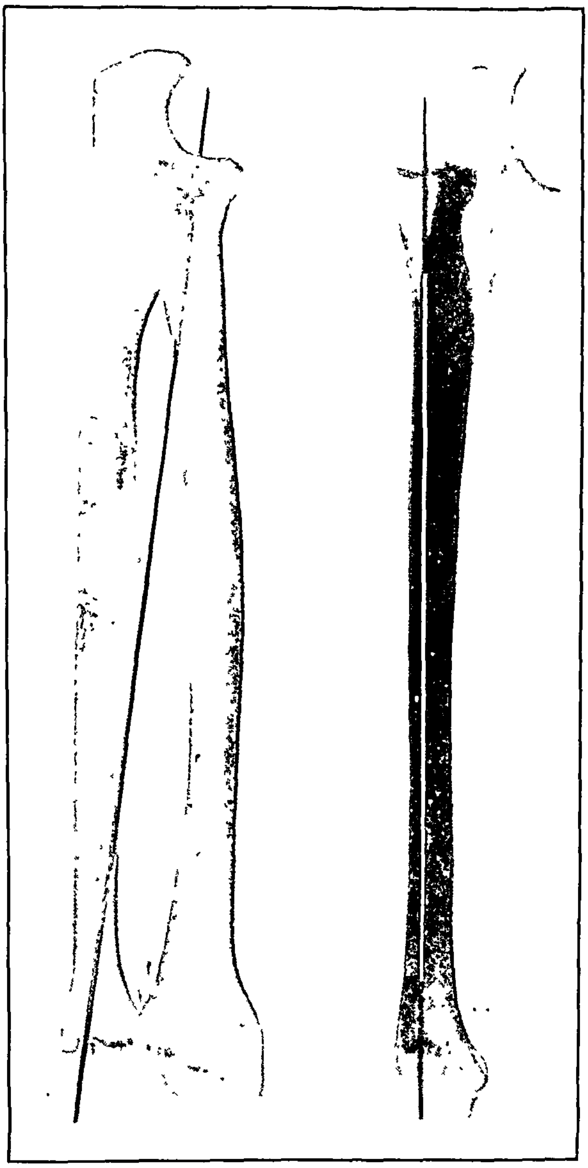


FIG. 2

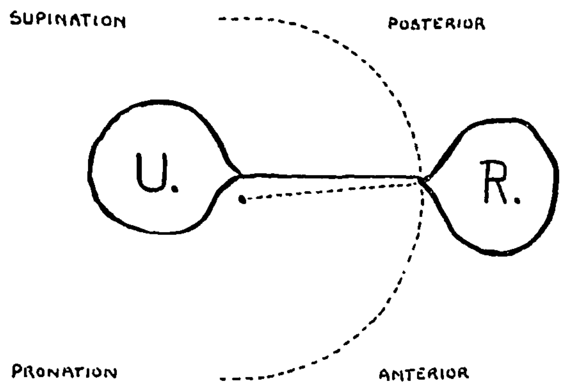


FIG. 3

Fig. 2: Roentgenograms of normal radius and ulna, with wire drilled along axis of rotation of radius.

Fig. 3: Sectional diagram of radius and ulna, showing arc of rotation of radius as a dotted line, with interosseous ridge of ulna lying just behind center of rotation.

tightening-slackening effect of the slight piston movement of the radius during pronation and supination; as a result, the interosseous membrane retains equal tension throughout the full range of rotation. In other words, for all practical purposes, one can disregard the slight piston movement of the radius and the slight displacement of the interosseous ridge of the ulna behind the axis of rotation, because the effects of these two factors on the interosseous membrane balance one another. The interosseous border of the ulna can then be regarded as actually corresponding to the line of the axis of rotation of the radius,—at least for the purpose of simplifying this study of supination and pronation.

FIG. 4
Normal arthrograms of inferior radio-ulnar joint.

The *triangular fibrocartilage*, or articular disc, is the main ligament binding the lower end of the radius to the ulna. At its base the articular disc is attached to the radius; at its apex it is inserted into the radial aspect of the styloid process of the ulna. From its other two sides, capsular fibers pass to the anterior and posterior surfaces of the head of the ulna. The articular part of the carpal surface of the head of the ulna consists of a small triangular area of cartilage, occupying the sector adjacent to the radius. The remaining two-thirds of the head give rise to lax fibers, which blend with the triangular fibrocartilage. A moment's consideration will show that, in supination and pronation, the articular disc will glide to and fro over the head of the ulna. Figure 4 shows the appearance of normal arthrograms of the joint space between the head of the ulna and the fibrocartilage.

Normally, pronation is limited by the crossing of the radius on the ulna and the trapping of the deep flexor muscles of the forearm between these two bones. The normal limiting factor in supination is more difficult to ascertain, but it appears to be caused by the posteromedial edge of the lower end of the radius becoming impinged against the tendon of the extensor carpi ulnaris, as it lies in its groove.

LIMITATION OF ROTATION FOLLOWING UNION OF FOREARM FRACTURES WITHOUT DISPLACEMENT

A consecutive series of 637 forearm fractures, excluding any with imperfect reduction or malalignment, was studied; and, once firm union had occurred, measurements were made of supination and pronation. Figure 5 shows the average combined limitation of supination and pronation for fractures of the radius and ulna, respectively, at the different levels. It will be seen from this graph that, with the exception of some fractures of the head of the radius, fractures above the level of the interosseous membrane do not cause limitation of rotation, once union has occurred. Fractures of the radial styloid are also in this category.

Colles's Fracture

In patients with Colles's fracture, limitation of rotation develops; this persists for many months and is sometimes permanent. These patients have pain over the head of the ulna when supination or pronation is forced.

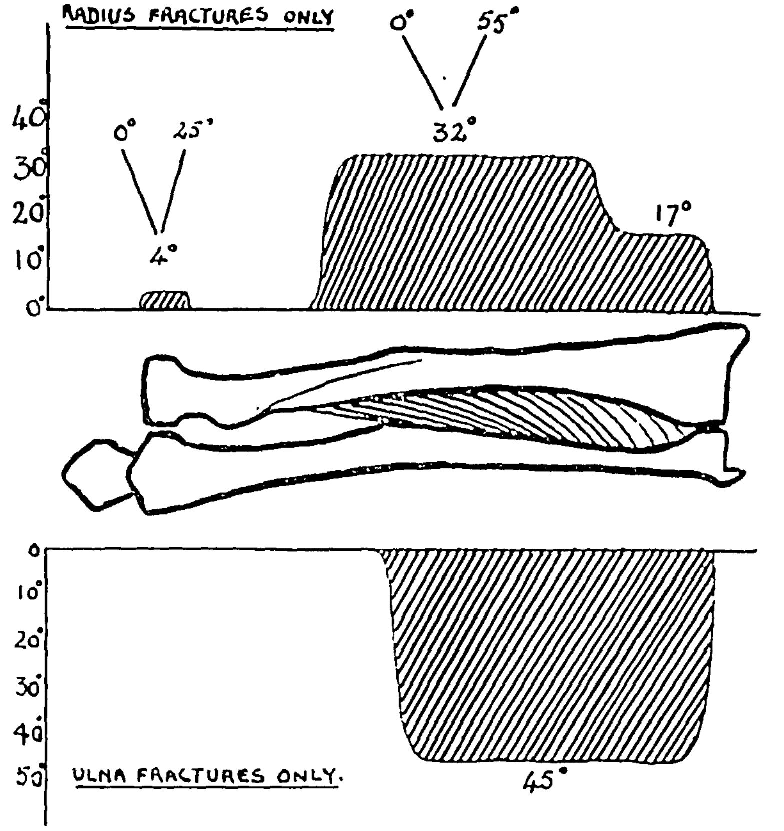


FIG. 5

Graph, based on 637 cases, shows average limitation of rotation in fractures at different levels.

When displacement of a Colles's fracture occurs, a strain is put upon the articular disc. Either this disc ruptures or, more frequently, the styloid process of the ulna, to which the triangular fibrocartilage is attached, is fractured at its base and displaced laterally to the same extent as the lower fragment of the radius. When reduction is effected, the semirigid articular disc pushes the ulnar styloid back into position. When the fibrocartilage is displaced, the capsular fibers passing from it to the head of the ulna are torn. Healing of this torn capsule results in adhesions and fibrosis, and a good deal of the joint space between the articular disc and the head of the ulna may be obliterated.

As a result of these changes, the triangular fibrocartilage can no longer glide freely to and fro on the head of the ulna during supination and pronation; and thus the limitation of supination and pronation and the associated pain are produced. Some degree of fibrosis may also extend directly between the radius at the site of the fracture and the lower end of the ulna, but this is not the main factor in causing limitation of rotation.

Investigation of this problem was done first by taking arthrograms of the joint space between the head of the ulna and the fibrocartilage. Uroselectan was injected through a needle passed from the dorsum of the wrist, and the joint was distended with the opaque medium. Figure 6 shows the appearance in a patient who had 90 degrees of limitation of supination and 40 degrees of limitation of pronation, nine months after reduction of a Colles's fracture. In all the cases of Colles's fracture with limitation of rotation which were investigated, some degree of obliteration of this joint space could be demonstrated.

Because the main displacement of the lower radial fragment is backward, it is to be expected that the anterior part of the capsule will be damaged more than the posterior part, and supination might be expected to be more limited than pronation. Measurements showed that limitation of supination was usually twice as great as limitation of pronation. The degree of limitation of supination and pronation is quite unpredictable. There appears to be no relation between the degree of the original displacement and the extent of loss of rotation, nor does perfect reduction necessarily ensure a full return of rotation.

Further study into the cause of limitation of rotation was done on twenty-four patients subjected to operation, and the dissections confirmed what had been inferred from the arthrograms. In no instance was any arthritic change found in the cartilage of the lower end of the ulna.

Fractures of the Head of the Radius

Most fractures of the head of the radius produce no limitation of rotation. The ones which do are usually those with comminution or marked displacement,—in other words, those subjected to operation. There is no doubt that excision of the whole head is better

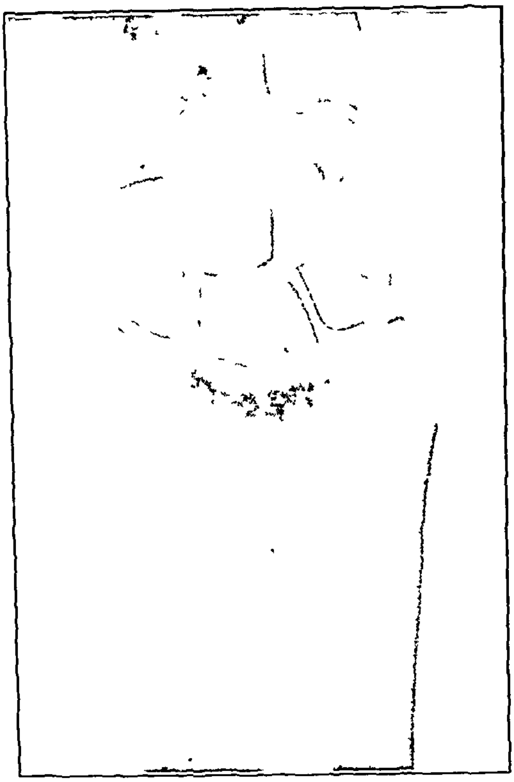


Fig. 6

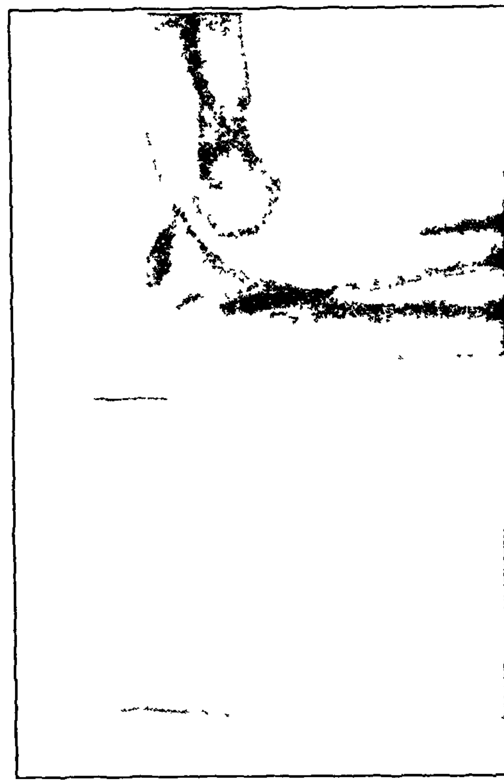


Fig. 7

Fig 6. Arthrogram of lower radio-ulnar joint in a case of old Colles's fracture with marked limitation of pronation.

Fig. 7: The upper roentgenogram shows a typical fracture of the head of the radius with dislocation of the elbow. The lower roentgenogram, taken a year after complete excision of the head, shows the new-bone formation on the anterior aspect of the neck.

than excision of a fragment of the head of the radius. Even with careful excision of the whole head, most patients have varying degrees of limitation of rotation, and in many cases this loss is considerable. Some limitation of extension of the elbow also frequently results.

The worst results occurred in those cases in which fracture of the head of the radius was associated with posterior dislocation of the elbow. There were seven such cases in this series. Closed reduction of the dislocation was done, and the head of the radius was then excised. In all cases a mass of callus formed on the anterior aspect of the neck and infiltrated into the adjacent muscles (Fig. 7); there was consequently a severe restriction of rotation, as well as of extension In the uncomplicated fractures of the head of the radius treated by excision, callus formation was singularly absent; and any limitation of rotation which occurred was due to adhesions between the joint capsule and the raw bony surface of the neck.

It has been rare to find any complaint of pain at the wrist due to damage to the articular disc, either before or after excision of the head of the radius; and while an injury to the fibrocartilage may occur, it is seldom of any clinical significance.

Fractures of the Radius and Ulna at the Level of Attachment of the Interosseous Membrane

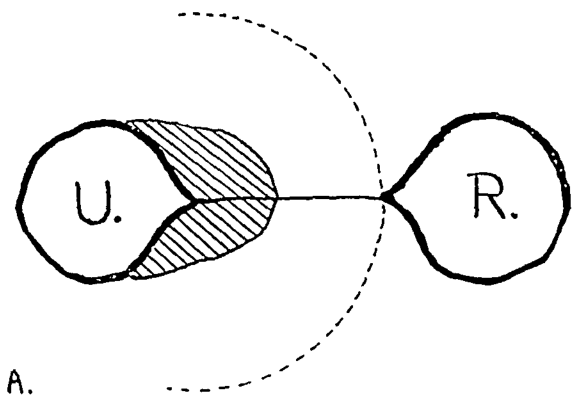
Since the normal range of pronation is checked by the radius crossing over the ulna and compressing the deep flexor muscles between the two bones, anything encroaching upon this space, such as fibrous tissue, callus formation, or oedema and hemorrhage, will alter the compressibility of the flexor muscles and limit pronation. It is therefore to be expected that, in all fractures of the middle third of the radius or ulna, some loss of

pronation will ensue and will last for a considerable time after union has occurred. Assessment of the other factors limiting rotation is therefore based upon measurements of supination rather than of pronation.

Isolated Fractures of the Ulna

Some degree of loss of rotation is present for a time after union of all ulnar fractures at the level of attachment of the interosseous membrane. Fibrosis or callus rarely extends far enough to involve the radius, and so limitation of rotation must be due to some other factor. The obvious cause is fixation of the adjacent interosseous membrane in the callus and fibrous tissue. Figure 8, *A* shows how this loss of rotation is brought about. The segment of interosseous membrane involved must tighten in supination and in pronation, and so restrict these movements.

In actual practice, the restriction of rotation in isolated ulnar fractures is rarely permanent; in most cases, a return to almost full rotation occurs. This is probably due to the fact that isolated fractures of the ulna are usually displaced very little; the articular-disc attachments and the ulnar styloid usually escape damage (see section on *Isolated Fractures of the Radius*); any limitation of rotation is not associated with much pain, and therefore the affected tissues are stretched by the patient's constant efforts at rotation.



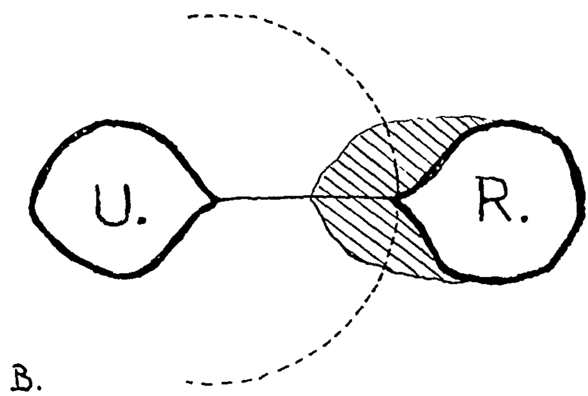


FIG. 8

Diagrams to illustrate how fixation of the interosseous membrane by callus or fibrosis around the ulna restricts the range of rotation; but around the radius the range of rotation is not restricted.

Isolated Fractures of the Radius

A study of these cases shows that they may be divided into two distinct classes: Group 1 includes those with no loss of rotation (except for slight loss of pronation, as explained previously), and Group 2 includes those with definite loss of rotation.

Figure 8, *B* shows that callus or fibrosis, extending into the interosseous membrane from the radius, cannot affect the range of rotation of the radius. What, then, is the explanation for the loss of rotation in the cases in Group 2? In those cases it is found that the attachments of the articular disc are torn. Upon forcing rotation, the patient complains of pain at the head of the ulna; the cause of the limitation of rotation is, in fact, precisely the same as in Colles's fracture,—namely, adhesions, fibrosis, and shortening of the attachments between the triangular fibrocartilage and the ulna. The partial obliteration of the joint space between the triangular fibrocartilage and the head of the ulna can be demonstrated readily by arthrogram (Fig. 9). In this arthrogram, done on a patient who had sustained a fracture of the mid-shaft of the radius, the partial obliteration of the joint space is apparent. A rupture of the articular disc, close to its radial attachment, had occurred; and the uroselectan may be seen, passing through the gap into the wrist joint. This type of rupture of fibrocartilage is more common in fractures of the shaft of the radius than in Colles's fractures, where fracture of the ulnar styloid is the usual associated injury.

Isolated fractures of the shaft of the radius, with displacement, demand careful treat-

ment. They are peculiarly apt to become redisplaced in plaster, even when a perfect reduction has been accomplished; and the redisplacement is accompanied by a dislocation at the inferior radio-ulnar joint, since the main ligament (the articular disc) holding the bones in relation to each other is often avulsed. Certainly, where the fracture line in the radius is oblique, open operation and fixation of the fragments by an inert metal screw or a plate should be done. The operation will cause some increase in the fibrous-tissue reaction around the fracture; but any further involvement of the interosseous membrane from the radial side will not affect the range of rotation.

Fig. 9

Arthrogram of the inferior radio-ulnar joint in a case of fracture of the mid-shaft of the radius.

Fractures of the Shafts of the Radius and Ulna Above the Level of the Interosseous Membrane

These fractures are rare. and there were only seven in this series. In all, union occurred with minimum displacement; and, once the fractures had united, there was no loss of supination or pronation. The absence of any limitation of rotation appears to be related to the absence of the interrosseous membrane at this level, although the fundamental factor probably is that at this level the movement of the radius is almost entirely a rotary one around its axis, which lies mainly within the shaft. The radius in its upper third, therefore, does not swing around the ulna; and fibrous tissue or callus formation around the ulna will not affect supination or pronation, unless it extends so far as actually to bind the radius and ulna together.

Fractures of Both Radius and Ulna

Limitation of rotation is due to the summation of the factors present in fractures of the radius and ulna, respectively. The triangular fibrocartilage often escapes damage in double fractures of the forearm, so that the fractured ulna is the main cause of limitation of rotation.

CASES IN WHICH ANGULATION OR DISPLACEMENT ADDS TO THE LIMITATION OF ROTATION

Lateral displacement is not very important, provided the alignment is good; but occasionally a considerable degree of lateral displacement of both bones may contribute to the development of cross union (Fig. 10-A).

Malalignment is a much more frequent cause of loss of rotation. The commonest error in reduction of a fracture of both bones of the forearm is failure to align the bones to their normal, anteriorly concave curve. Then, after union has occurred, there is an anterior projection of both bones when the forearm is in supination. In pronation, the radius rotates so that the abnormal projection now presses against the similar projection on the ulna, and hence marked limitation of pronation results. The same thing may occur in fractures of the radius alone, but of course the limitation of pronation is much more marked when both bones are angled.

Rotational Displacement of the Fragments in Fracture of the Shaft of the Radius: A pure rotation movement of either the upper or lower fragment of the radius does not occur. The fragments can only move in their normal arc around the ulna, although, in the case of the upper fragment, the purely rotary component is the main one. In the case of the lower fragment, the swinging bucket-handle movement is the major component. This being the case, it follows that, if there is a rotary displacement between the two fragments, the frag-

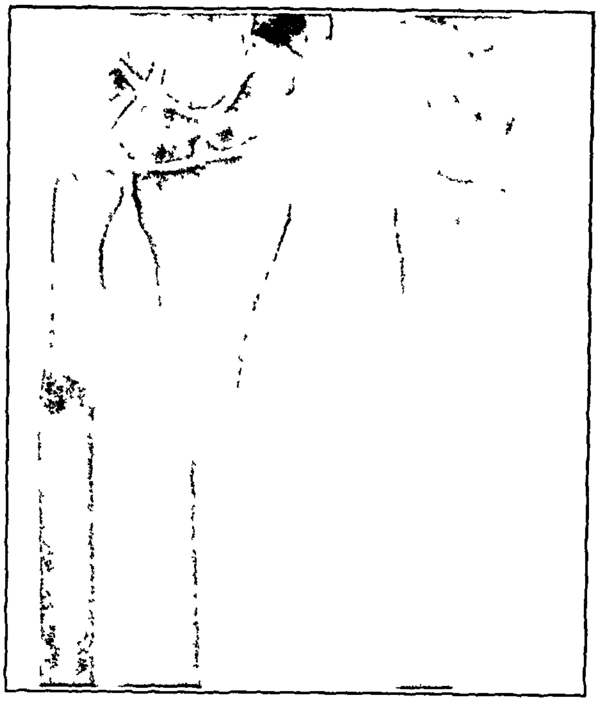


Fig. 10-A


Fig. 10-B

Fig. 10-A: Roentgenograms show fracture in good alignment, but lateral displacement has almost resulted in cross union.
Fig. 10-B: Same patient, treated by Baldwin's operation.

ments will also be out of alignment. In practice, therefore, one has only to get the fragments of the radius in perfect alignment to be sure of correcting all rotary displacement. The old rule that in fractures above the insertion of the pronator teres the upper fragment is supinated by the biceps muscle, while fractures below this level have the upper fragment in a mid-position of rotation, appears to be generally correct. The only safe rule in reduction, however, is to place the forearm in such a degree of rotation that exact alignment is secured.

THE PREVENTION AND TREATMENT OF LOSS OF ROTATION

Children never seem to develop permanent loss of rotation, provided a reasonably good closed reduction of the fracture has been obtained. Therefore the following remarks need only be considered as applying to adults.

Fractures of the Head of the Radius

The treatment is largely prophylactic. All patients with fractures of the head of the radius should practise full passive rotation, as well as active rotation, from the day of injury. Apart from this, the orthodox treatment is carried out, the elbow being held in flexion by a collar-and-cuff sling.

As mentioned previously, it is the severe fractures, mainly those in which the whole head has had to be excised, in which marked limitation of rotation is apt to develop; and early rotation should be carried out regularly in such cases. In the past five years, thirty-two cases of fracture of the head of the radius have been treated by excision of the whole head, and, with only a few exceptions, the performance of supination and pronation from the day after operation has resulted in an almost complete return of rotation. There has also been a marked improvement in the final range of extension at the elbow; and in almost all cases a full range of all elbow movements has resulted. The explanation of the final full range of extension probably is that adhesions which form between the capsule and the raw bony surface of the radius are kept long and lax by the early rotation, and so do not limit extension. The general rule—namely, that forced flexion and extension of an injured elbow should be avoided—should probably be supplemented by the clause that active and passive

supination and pronation should be maintained from the day of injury, particularly in cases of fracture of the head of the radius. Even with early rotation, callus formation is singularly absent.

The exceptional results occurred in seven patients in whom a mass of callus developed on the anterior surface of the neck of the radius; severe restriction of rotation resulted, as well as considerable loss of extension (Fig. 7). All were cases of comminuted fracture of the head of the radius, associated with posterior dislocation of the elbow, in which excision of the head was carried out after closed reduction of the dislocation. Two of these patients performed no rotation exercises, while the others practised supination and pronation immediately after operation, but the final results were equally bad in all cases. The last two cases of fracture-dislocation were treated by closed reduction of the dislocation, followed by excision of the head five weeks later. This delayed excision of the head did not prevent the formation of a mass of callus, and the final results were no better than in those patients treated by immediate excision of the head. In four of the cases, the mass of callus was finally excised at a second operation about six months afterward, but improvement in function of the elbow joint was only moderate.

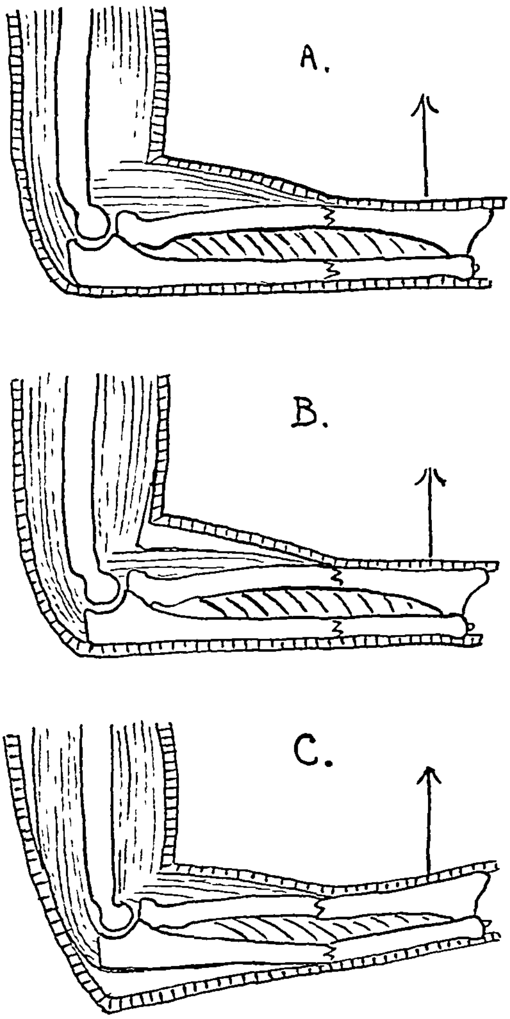


Fig. 11

Diagrams to illustrate how angulation of a fracture of the radius and ulna can occur in plaster. The arrow indicates where the plaster is supported by a sling.

Fractures of the Shafts of the Radius and Ulna

Open operation upon a fracture of the radius and ulna inevitably increases the soft-tissue damage and the reaction around the bone, and for this reason operation usually produces still further loss of rotation. Certain oblique fractures of the forearm bones, however, require internal fixation if displacement is to be avoided. As explained before, an excess of fibrous tissue or callus around a fracture of the radius will not affect rotation, apart from some inevitable loss of pronation; and so the author makes it a practice, whenever possible, to fix only the fracture of the radius. Usually, once the fracture of the radius has been well reduced and plated, the fracture of the ulna is found to be relatively stable; and further fixation of the forearm bones can be secured with plaster. Open manipulation of fracture of the ulna may result in an increase in callus and fibrous tissue around the fracture; and, unless absolutely necessary, operation upon the ulna should be avoided.

One of the complications frequently encountered in dealing with forearm fractures is the angulation which often develops while the well-set fractures of the radius and ulna are held in an unpadded plaster. The explanation of this apparently anomalous development of deformity is simple. When the forearm is first set and fixed, the plaster fits the contours of the arm closely (Fig. 11, *A*). Much of the weight of the plaster is taken by the collar-and-cuff sling tied around the wrist, but the brachioradialis muscle also supports a good

deal of the weight. This muscle, however, which acts only upon the elbow joint, has no opportunity of contracting so long as the elbow is immobilized; the muscle therefore atrophies rapidly, and a space forms beneath the plaster, over the upper surface of the proximal half of the forearm (Fig. 11, *B*). The plaster cast then sags here and, as the distal fragments of the forearm bones are still firmly held—since they are surrounded mainly by tendons—angulation occurs (Fig. 11, *C*). The method of preventing this angulation is to incorporate a calico bandage in the last layer of plaster at a point just below the elbow joint; the calico bandage fixed at this level is the only suspension allowed. The author has employed this form of suspension in all cases of forearm fracture for the last three years, and has had no cases of angulation occurring under plaster during this time. The present universal method of suspending plasters for forearm fractures by means of collar-and-cuff slings should be completely abandoned.

Cross Union

Open operation on the radius and ulna is the commonest cause of cross union, and it is probable that at such operations the fault lies in unnecessary exposure of the interosseous aspect of the bones, as when the ends of the bones are made to extrude through the wound. Such a procedure is particularly apt to be followed by cross union in children, but fortunately successful closed manipulative reduction can almost always be done at this age.

Complete bony cross union is rare, although a lesser degree of callus formation is more often encountered. Even without complete bony fusion, the rotation movement may be almost lost.

Once cross union has become established, or a condition close to this has developed, what can be done? The cases most easily treated are those in which the cross union is in the lower third of the forearm. There the treatment simply consists in excision of one inch of the ulna, with its periosteum, at the site of the fracture, as well as the mass of callus between the bones (Baldwin's operation) (Fig. 10-B). A full range of supination and pronation is obtained, although there is sometimes slight loss of gripping power.

Where cross union has occurred in the middle third of the forearm bones—and this is the commonest site—treatment is much more difficult. The surgical treatment of such a condition at this level is to excise one and one-half inches of the ulna, with the adjacent mass of callus and the surrounding periosteum. The mass of flexor and extensor muscles is then carefully sutured together to obliterate any dead space, and the wound is closed. After a three-month interval, when roentgenograms show no new callus formation, a whole-thickness fibular graft is inserted across the gap. Two patients have been treated by this method, and in each case a 75 per cent. range of rotation was regained.

The rationale of this treatment can be understood by considering Figures 8, *A* and 8, *B*. Obviously, it is the mass of callus around the ulna which must be removed. The operation, if performed successfully, produces a condition in which the remaining callus around the radius leaves rotation quite unaffected, provided a supple membranous scar takes the place of the mass of callus around the ulna.

Colles's Fracture

It is unusual for a severe permanent limitation of rotation to develop in a patient with Colles's fracture, but sometimes this does occur and demands treatment. Forced passive movements and other forms of physiotherapy seem to have little effect, and forced manipulation under anaesthesia usually causes a spiral fracture of the lower third of the ulna.

Excision of the head and neck of the ulna, with its periosteum, has proved an easy and reliable way to recover full rotation in such cases. The bone is exposed through a posteromedial incision, and the dissection is done extraperiosteally with a scalpel. The ulna is divided one inch above the wrist joint with bone shears, and the head of the ulna is dissected off the adherent triangular fibrocartilage, starting from the radial side. The triangular fibrocartilage and the ununited ulnar styloid are left *in situ*, so that the wrist joint is not

opened. The removal of the periosteum ensures the absence of any new-bone formation. Both active and passive rotation are practised from the day after operation. The immediate result is an increase in the limitation of supination and pronation, which may persist for as long as six weeks. Thereafter a full range of supination and pronation rapidly develops. The results of this operation are particularly gratifying to those patients in whom impaction of the fracture and an ugly projecting ulnar head had been present, as well as the loss of rotation. After the postoperative swelling has subsided, the appearance of the wrist is only slightly different from normal. The tendon of the extensor carpi ulnaris prevents the appearance of a hollow.

Twenty-four such operations have been done in the past four years,—nearly all in females. Twenty of the patients were discharged without any complaint of disability and with full supination and pronation. The other four patients either had slight limitation of rotation, or had a sense of weakness in the wrist during such actions as carrying a shovelful of coal or lifting down a heavy pot from a shelf; but even in these cases the return of rotation was well worth the slight weakness which ensued.

LOSS OF ROTATION DUE TO CAUSES OTHER THAN FRACTURES

Volkmann's Contracture

In this condition the flexor muscles are replaced by a mass of fibrous tissue. As this fibrous tissue contracts, the forearm is pulled into pronation and all power of supination is lost. Little attention seems to have been paid to this pronation deformity, and in severe cases of Volkmann's contracture it is of little importance. In the mild cases, however, physiotherapy should be directed toward preventing this permanent pronation deformity, as well as toward stretching the flexor tendons.

Loss of Rotation in Paralytic and Spastic States

In Erb's paralysis, supination of the forearm is lost to a certain extent. When a patient is seen several years after the birth injury, one may find that the degree of residual paralysis is only slight; and certainly the power of the biceps often appears ample to effect supination. The cause of the loss of supination is to be found in a study of the curvature of the ulna. In infancy, the child, finding supination difficult, does not perform this movement; and so the traction effect of the interosseous membrane, in causing the interosseous edge of the ulna to mold itself along the axis of rotation of the radius (Fig. 2), is absent. The ulna becomes curved, so that its interosseous border lies in front of the axis of rotation of the radius. In later years, when supination is attempted, the position of the interosseous border of the ulna in relation to the axis of rotation of the radius results in the membrane becoming taut, and in this way supination is permanently restricted.

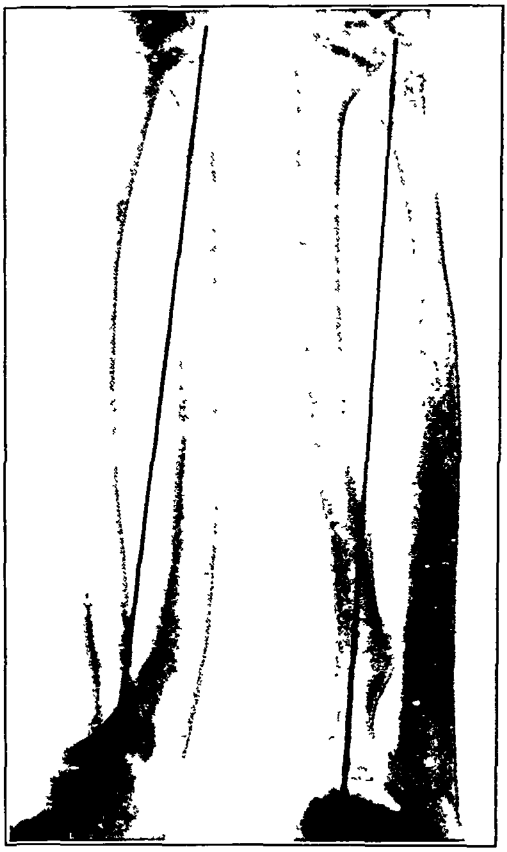


FIG. 12-A

Roentgenograms of forearm bones in patient with spastic paralysis of the right arm, present since birth. Supination was almost lost (see Fig. 12-B). Note how the axis of rotation of the radius deviates from the line of the interosseous ridge of the ulna.

FIG. 12-B FIG. 12-C

Fig. 12-B: Patient with mild spastic paralysis of right arm and loss of supination since birth.
Fig. 12-C: Range of supination six months after excision of the head of the ulna.

A similar alteration in the curvature of the shaft of the ulna may develop in cases of mild spastic paralysis of the upper limb (Fig. 12-A) or in infantile paralysis; and in later years this abnormal ulnar curvature will prevent successful cooperative attempts at rotation.

When the rotator muscles of the forearm are strong and controlled, considerable improvement in the range of rotation can be obtained by performing an osteotomy of the upper third of the ulna, and realigning the shaft so that the interosseous border conforms to the axis of rotation of the radius. This realignment is obtained simply by forcing the forearm into full supination or pronation after osteotomy, and fixing it in plaster until union is sound; the interosseous membrane thereby pulls the ulna into the necessary alignment.

The author has done this only twice; others, including Blount[1], have done it frequently, but they have been under the impression that a rotation osteotomy of the ulna had been done. A study of the roentgenograms, however, shows that, whether or not rotation of the ulna was effected, a very good realignment of the interosseous border of the ulna along the axis of rotation of the radius was made; the improved rotation was unwittingly caused by the realignment of the ulna, and was not due to rotation osteotomy.

In the past, limitation of supination has frequently been ascribed to spasm or contracture of the pronator teres; and tenotomy of that muscle has often been done without any obvious improvement in the supination range. An alternative to osteotomy and realignment of the ulna in such cases is to excise the head and neck of the ulna. When this has been done, the ulna can swing toward the radius when the interosseous membrane tends to tighten; and so the main factor limiting supination is abolished and an increased range of supination results. Two cases of spastic hemiplegia, present since birth, have been treated in this way; and in both an almost full range of rotation has resulted (Figs. 12-B and 12-C).

1. BLOUNT, W. P.: Osteoclasis for Supination Deformities in Children. J. Bone and Joint Surg., 22: 300-314, Apr. 1940.

END RESULTS OF BONE-GRAFTING FOR NON-UNION OF THE CARPAL NAVICULAR *

BY GORDON MURRAY, M.D., TORONTO, ONTARIO, CANADA

It is now sixteen years since the first bone-grafting of the carpal navicular by this particular method[1] was carried out. The purpose of this presentation is to report the results of 100 such bone grafts for non-union of fractures of the navicular.

A further report on this procedure was thought advisable for two reasons:

1. The procedure has given excellent results, with good function of the wrist, in the vast majority of cases.

2. During World War II there have been several reports, especially from the Canadian military surgeons, on the results of bone-grafting; in most instances the reports were not favorable. After reading these reports and talking with several of the surgeons, the author believes that there are reasons why the results of these operations were not satisfactory.

In the first place, many of the operations were performed by men who had not seen the procedure carried out, and who were doing the operation for the first time. The operations were done by different operators, and many of the surgeons had not done more than one or two of the total series reported.

The second factor which may contribute to a failure is that an insufficiently large graft has been used. In one case not reported in this series, another operator had done a bone graft; he placed the graft in good position, but used a small piece of bone,—smaller than the size of a match.

From experience with the operation, the author believes that certain principles must be followed to obtain the best results.

1. The bone graft must be large. In other words, the drill which makes the hole must cut away a large proportion of the face of the fracture surface in both fragments. When this has been done and a large graft has been inserted to take its place, the surrounding bone becomes calcified and ossified and the union is satisfactory.

2. The graft must be well placed so that it goes through the distal fragment, across the fracture line, and well into the proximal fragment, so that there is no doubt regarding the contact of the graft with the proximal fragment.

3. The drill hole must not be so large that it cuts through the articular cartilage and bursts into any of the surrounding articulations.

4. After the bone graft has been placed in position, the final procedure must be to drive the distal fragment down firmly so that it is impacted against the proximal fragment; the graft must fit tightly enough to hold the fragments firmly in apposition.

5. There must be adequate splinting of the wrist, including all metacarpals and the proximal phalanges, or probably both phalanges of the thumb, so that the wrist and the first metacarpal are completely immobilized. This should be continued for a minimum of ten weeks and, where there is devitalization of the proximal fragment, for a much longer period. This time can be determined by the roentgenographic appearance of revascularization of the proximal fragment.

6. Splinting must be continued until there is roentgenographic evidence of union of the fracture. The graft must be united to both fragments, and the fracture line surrounding the graft must show trabeculae crossing it.

The question arises of whether cortical bone from the tibia, or cancellous bone from the ilium or elsewhere, should be used. In all the cases in this series, cortical bone—usually from the tibia—has been used, for the following reasons:

* Presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 28, 1946.

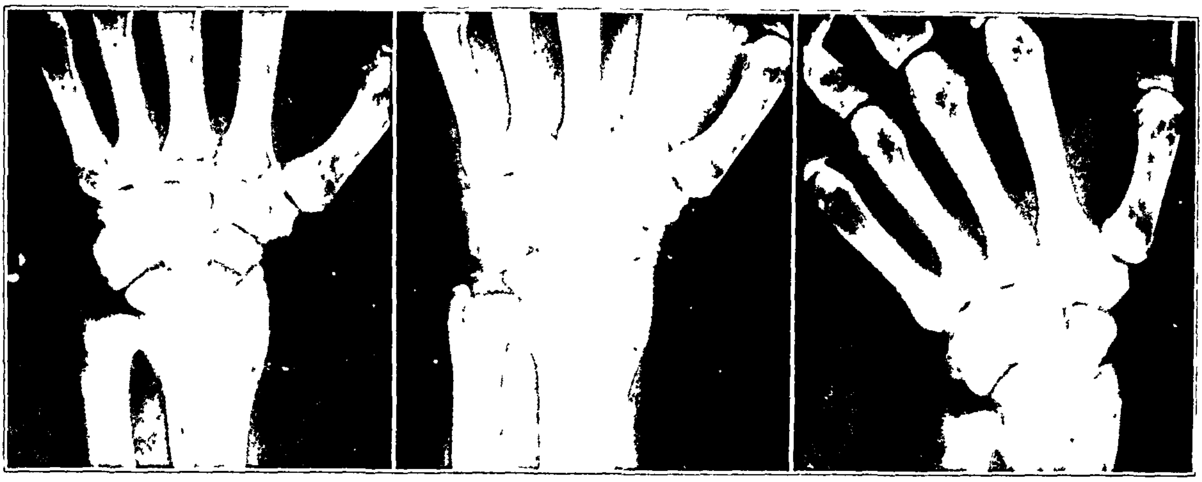


Fig. 1-A Fig. 1-B Fig. 1-C

Fig. 1-A: J. K., Case 11. Shows non-union of a fracture through the waist of the navicular of one year's duration. Some arthritic changes are present in the wrist joint, as indicated by an elongation of the styloid process of the radius. In spite of this, bone-grafting was undertaken.

Fig. 1-B: Shows the graft in position, with beginning union of the graft to both fragments and union of the fracture.

Fig. 1-C: Shows the result after four years. The arthritic changes have not increased. The graft has united solidly. The fracture line has disappeared and the end result is good. This patient has an excellent range of motion; the functional result is estimated at 88 per cent.

1. The strong, heavy bone can be chiseled into the proper shape, and it can be driven in firmly and handled without breaking into pieces.

2. It maintains its strength, even with firm impaction of the fragments.

3. In this series of cases, the bone has proved sufficiently osteogenic to do its work. While cancellous bone may have better properties in this respect, still the results here justify the procedure. Cancellous bone might effect an earlier union of the fracture, but the stability and other qualities of the cortical bone produce results which are difficult to obtain with the cancellous bone.

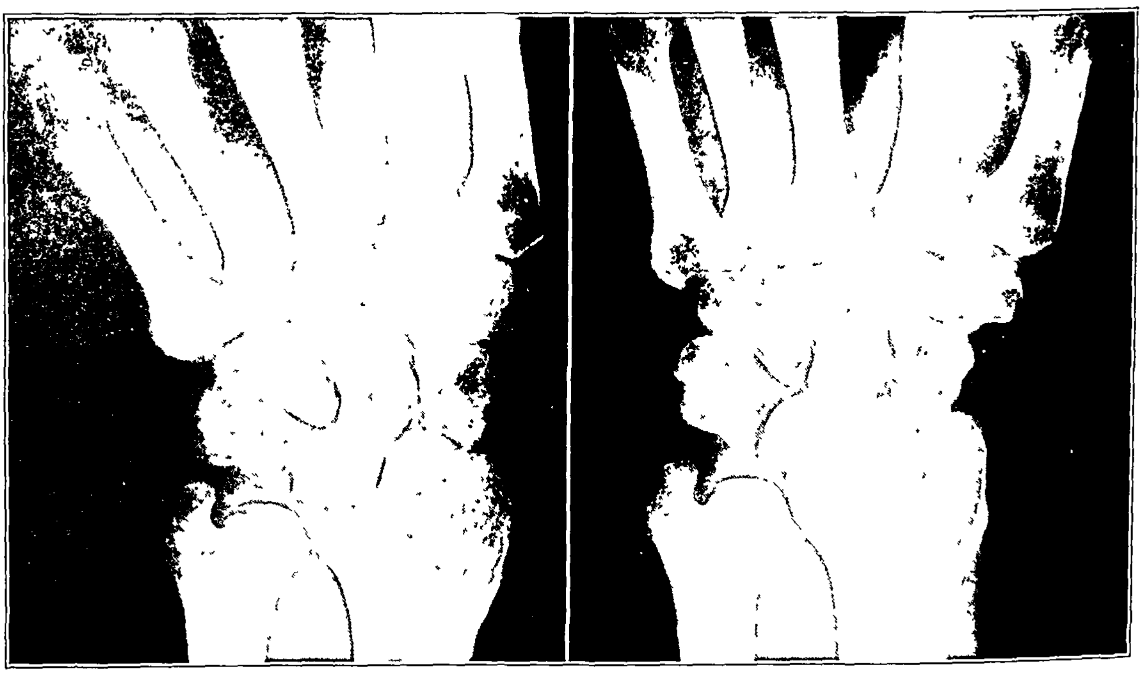


Fig. 2-A Fig. 2-B

Fig. 2-A: K. L., Case 21. Shows ununited fracture of navicular of seven months' duration. There is aseptic necrosis of the proximal fragment, but no arthritic or degenerative changes are present in the wrist joint.

Fig. 2-B: Shows the result six months after bone-grafting. The fracture has united, and the graft has united to both fragments. The proximal fragment still shows aseptic necrosis, as does the adjacent lunate bone. Revascularization of the proximal fragment can be expected to occur as the months pass.

RESULTS

Out of 100 cases included in this report, bony union occurred in ninety-six, and the function in all of these was very satisfactory. In some patients the range of motion was 100 per cent. in all directions, without any disability or discomfort. In some of the others,

FIG. 3-A

FIG 3-B

Fig. 3-A: F. D, Case 43. Shows a mid-carpal dislocation, with fracture of the navicular

Fig 3-B: Open reduction has been performed Roentgenogram shows a good reposition of the dislocated carpal bones, with a bone graft in the navicular The proximal fragment of the navicular shows marked aseptic necrosis.

FIG 3-C

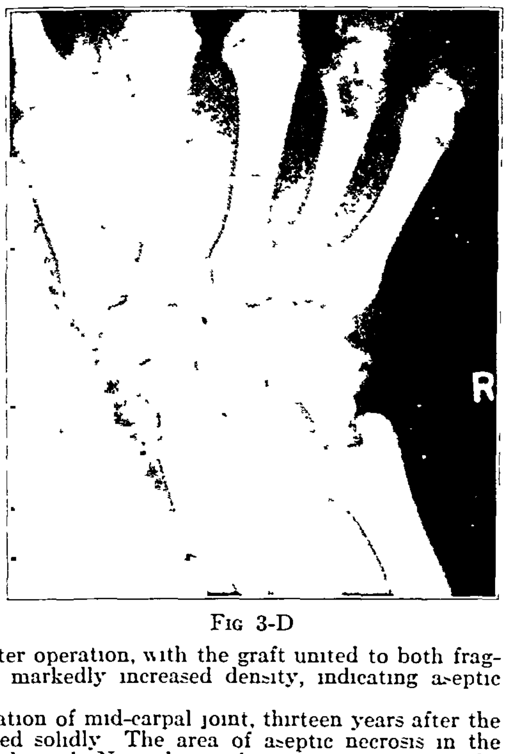


FIG 3-D

Fig 3-C: Shows beginning union of fracture after operation, with the graft united to both fragments. The proximal fragment, however, shows markedly increased density, indicating aseptic necrosis

Fig. 3-D: End result after bone graft for dislocation of mid-carpal joint, thirteen years after the operation for reduction. The navicular has united solidly The area of aseptic necrosis in the proximal fragment has become completely revascularized No arthritic changes are present in the joint. The patient has an excellent range of motion; he has returned to heavy laboring work and has continued at it for thirteen years

TABLE I

Data on 100 Cases of Bone-Grafting for Non-Union of the Carpal Navicular*

No	Patient	Age	Duration of Fracture Before Operation	Previous Treatment	Time Since Operation (*Years*)	Duration of Fixation After Operation	Time Between Operation and Return to Work (*Months*)	Union	Degree of Function (*Per cent.*)	Remarks
1	B.S.	31	6 mos.	Missed	16	12 wks.	4½	Yes	98	
2	F.S.	20	3½ mos.	Missed	15	12 wks.	3½	Yes	—	
3	W.M.	28	2½ mos.	Missed	15	12 wks.	5	Yes	95	
4	M.S.	30	4 mos.	Missed	14	13 wks.	5½	Yes	95	
5	G.H.	21	3 mos.	Missed	14	Few days	3 wks.	No	—	
6	K.G.	23	14 mos.	Missed	9	12 wks.	7	Yes	75	
7	G.G.	42	2 yrs.	Missed	8	14 wks.	8	Yes	80	
8	E.R.	38	6 mos.	Plaster, 6 wks.	4	12½ wks.	5½	Yes	90	
9	N.B.	28	2½ yrs.	None	4	14 wks.	8	Yes	75	
10	C.R.	30	6 mos.	None	3	12½ wks.	6½	Yes	85	
11	J.K.	28	1 yr.	None	4	13 wks.	7½	Yes	88	
12	R.A.	31	5 mos.	Plaster, 2 mos.	3	32 wks.	9½	Yes	75	Aseptic necrosis, proximal fragment.
13	T.M.	38	8 wks.	Plaster, 8 wks.	3	16½ wks.	8½	Yes	68	Mid-carpal dislocation and fractured navicular.
14	A.W.	32	Previous non-union	Bone graft by Dr.H.M.	3	20 wks.	6½	Yes	72	Previous bone graft for non-union.
15	J.G.	26	2½ yrs.	Plaster, 8 wks.	3	11 wks.	3¾	Yes	93	Some cystic changes in both fragments.
16	A.H.	41	6 mos.	Plaster	2	12 wks.	4	Yes	95	
17	R.J.	38	1½ yrs.	Missed	2	16 wks.	5	Yes	88	
18	M.B.	40	2 mos.	Plaster, 2 mos.	2½	12 wks.	5	Yes	90	Severely comminuted fracture.
19	F.C.	32	5 mos.	Missed	2	13 wks.	5½	Yes	88	Aseptic necrosis, proximal fragment.
20	H.J.C.	29	5 mos.	None	2	14 wks.	5	Yes	92	
21	K.L.	19	7 mos.	Plaster, 2 mos.	2	16 wks.	6	Yes	80	Aseptic necrosis of lunate bone.
22	A.B.	46	4 yrs.	None	2	20 wks.	—	No	—	Aseptic necrosis, proximal fragment. Other arm missing.
23	C.R.	20	1 yr.	None	2	12 wks.	4½	Yes	96	
24	J.P.	19	1½ yrs.	Missed	1½	13 wks.	6½	Yes	95	
25	Dr.K.	42	10 yrs.	None	1½	14 wks.	6½	Yes	65	Moderate arthritis present.
26	H.S.	32	2 yrs.	Splints	1	4 mos.	9	Yes	94	Aseptic necrosis of proximal fragment; revascularized.
27	J.B.	26	1½ yrs.	Splints	2	6 mos.	13	No	—	Aseptic necrosis of both fragments; finally fusion of wrist.
28	W.P.	31	3 yrs.	Missed	3	5 mos.	7	Yes	82	Moderate cystic degeneration.
29	R.S.	17	3 wks.	Splints	1	4 mos.	6	Yes	75	Mid-carpal dislocation also.
30	A.B.	22	4 mos.	Missed	1	4 mos.	7	Yes	90	Plus fracture, head of radius.
31	C.R.	25	5 yrs.	None	1½	4½ mos.	7½	Yes	84	Moderate aseptic necrosis, proximal fragment.
32	A.B.	32	5 mos.	Splints	9	3 mos.	4	Yes	97	
33	B.H.	19	1½ yrs.	Splints	8	11 wks.	3½	Yes	99	
34	G.F.	21	4 mos.	None	6	3 mos.	4½	Yes	99	
35	T.G.	18	4½ mos.	None	8	3½ mos.	5	Yes	96	
36	M.G.	22	3½ mos.	None	12	3 mos.	4½	Yes	98	
37	L.L.	28	6 mos.	Missed	12	3½ mos.	5	Yes	95	
38	G.L.	21	3 mos.	Missed	11	3 mos.	4	Yes	98	
39	S.R.	26	6 mos.	None	11	3 mos.	4½	Yes	92	
40	N.S.	28	7 mos.	None	10	3½ mos.	5½	Yes	92	
41	G.E.	27	10 mos.	Splints	9	4 mos.	6½	Yes	94	

* With the exception of Case 9, all the patients in this series were males.

TABLE I (*Continued*)

No.	Patient	Age	Duration of Fracture Before Operation	Previous Treatment	Time Since Operation (*Years*)	Duration of Fixation After Operation	Time Between Operation and Return to Work (*Months*)	Union	Degree of Function (*Per cent.*)	Remarks
42	M.I.	38	3 mos.	None	7	3 mos.	5	Yes	96	
43	F.D.	32	1 mo.	Splints	13	4 mos.	9	Yes	90	Mid-carpal dislocation and aseptic necrosis.
44	G.M.	36	6 mos.	None	7	5 mos.	8	Yes	81	Aseptic necrosis, proximal fragment.
45	J.G.	30	3½ mos.	None	11	8 wks.	3	Yes	97	
46	A.M.	22	4 mos.	None	9	10 wks.	4	Yes	98	
47	H.K.	35	6 mos.	Splints	9	3 mos.	5½	Yes	90	
48	T.T.	28	5 mos.	None	6	3 mos.	4½	Yes	92	
49	A.T.	41	4½ mos.	None	9	3½ mos.	6	Yes	93	
50	H.T.	50	4 mos.	None	10	3½ mos.	5	Yes	90	
51	H.F.	17	3 mos.	Splints	8	3 mos.	4½	Yes	97	
52	J.F.	26	4 mos.	Splints	9	3½ mos.	5	Yes	92	
53	F.A.	24	5 mos.	None	8	3 mos.	5	Yes	96	
54	F.J.	42	3 mos.	None	7	3½ mos.	5	Yes	92	
55	S.B.	39	8 mos.	Missed	11	4 mos.	5½	Yes	87	
56	G.F.	41	3½ mos.	None	9	3 mos.	4½	Yes	92	
57	L.R.	21	6 mos.	None	5	3 mos	6	Yes	80	
58	M.G.	19	4 mos.	None	11	2½ mos.	4	Yes	98	
59	A.G.	39	11 mos.	None	6	5 mos.	5	Yes	92	
60	P.R.	31	6 mos.	None	12	3 mos.	5	Yes	94	
61	G.D.	24	7 mos.	Splints	4	3½ mos.	4½	Yes	90	
62	I.L.	25	3 mos.	Splints	5	3 mos.	5	Yes	9[illegible]	
63	S.M.	29	13 mos.	Splints	7	4½ mos.	6	Yes	84	Aseptic necrosis, proximal fragment.
64	M.H.	39	2½ mos.	None	8	3 mos.	4	Yes	98	
65	L.C.	46	4 mos.	Splints	9	3 mos.	4½	Yes	94	Aseptic necrosis, proximal fragment.
66	G.C.	35	2 yrs.	None	7	3½ mos.	6	Yes	94	
67	A.B.	29	4 mos.	None	10	3 mos.	4½	Yes	95	
68	A.M.	42	6 mos.	None	11	3 mos.	5	Yes	96	
69	L.C.	41	7 mos.	Splints	10	3½ mos.	4½	Yes	89	
70	M.J.	30	3 mos.	Splints	12	3 mos.	5	Yes	9[illegible]	
71	S.F.	20	1 yr.	None	6	3 mos.	5	Yes	90	Aseptic necrosis.
72	K.B.	34	6 mos.	None	8	3½ mos.	6	Yes and no	97	Non-union; regrafted and united.
73	J.H.	18	3 mos.	None	11	3 mos.	4½	Yes	99	
74	C.M.	40	1 yr.	None	6	4 mos.	6	Yes	90	
75	R.M.	28	4 mos.	None	5	3 mos.	4½	Yes	94	
76	A.W.	34	3 mos.	Bone-grafting	5	8½ mos.	6	Yes	90	Previous bone graft failed.
77	L.S.	50	6 mos.	Splints	5	3 mos.	[illegible]	Yes	88	
78	G.A.	21	3 mos.	None	10	3½ mos.	6	Yes	91	
79	F.A.	32	4 mos.	None	4	2½ mos	4	Yes	95	
80	L.B.	40	5 mos.	None	6	3 mos	4	Yes	98	
81	E.S.	29	8 mos.	Missed	9	3½ mos	5½	Yes	95	
82	M.L.	31	4 mos.	None	11	3 mos.	4½	Yes	92	
83	A.N.	35	7 mos.	None	7	3½ mos.	5	Yes	94	
84	A.W.	38	5 mos.	None	11	3 mos.	6	Yes	95	Aseptic necrosis.
85	N.D.	41	9 mos.	None	13	4 mos.	6	Yes	91	Aseptic necrosis.
86	D.H.	24	11 mos.	None	4	3½ mos.	5½	Yes	89	
87	F.D.	29	3 mos.	None	5	3 mos.	6	Yes	92	Aseptic necrosis.
88	S.E.	40	4 mos.	None	11	3½ mos.	4½	Yes	94	
89	M.G.	28	8 mos.	None	6	3 mos.	5	Yes	95	
90	A.K.	31	3 mos.	None	7	3 mos.	4½	Yes	94	
91	F.L.	34	4 mos.	None	6	3 mos.	5	Yes	96	
92	J.O.	42	5 mos.	Missed	7	3 mos.	4	Yes	92	
93	M.O.	22	3 mos.	Missed	3	3 mos.	4	Yes	98	
94	J.A.	29	2 yrs.	Missed	3	4 mos.	6	Yes	92	
95	O.S.	46	1 yr.	Missed	4	3½ mos.	5½	Yes	94	
96	J.B.	36	1 mo.	Splints	6	3½ mos.	7	Yes	86	Mid-carpal dislocation.
97	M.P.	26	4 mos.	Splints	4	3 mos.	4	Yes	94	
98	J.M.	25	5 mos.	None	6	3 mos.	4½	Yes	95	
99	F.N.	20	3 mos.	None	7	3 mos	4	Yes	95	
100	J.N.	39	15 mos.	Splints	7	4 mos	5½	Yes	92	

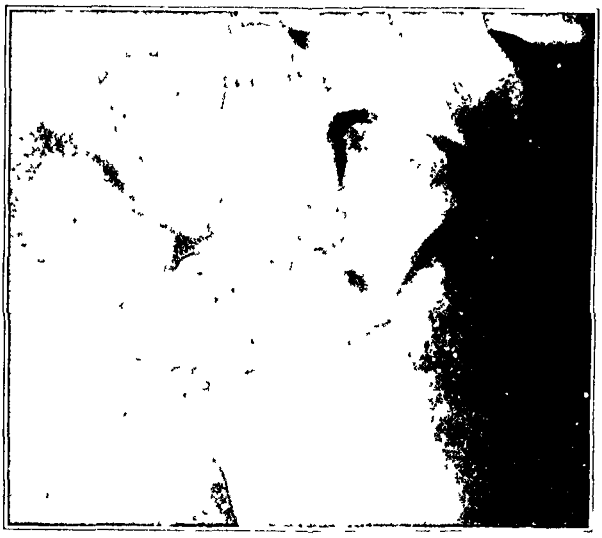


FIG. 4-A

FIG. 4-B

Fig. 4-A: F. S., Case 2. Ununited fracture at the junction of the proximal and middle thirds of the navicular.
Fig. 4-B: Bone graft in position after operation.

FIG. 4-C

FIG. 4-D

Fig. 4-C: Shows union of the fracture.
Fig. 4-D: Roentgenogram of end result, sixteen years after bone-grafting, shows solid union of the fracture. The graft is still visible. The bone is viable throughout. There is no arthritis in the wrist joint and no degenerative change as a result of either the fracture or the bone-grafting.

where there had been prolonged non-union and where a doubtful amount of arthritis was present in the wrist, the range of motion did not return to normal. However, the range of motion was useful and painless, and was sufficient so that the patients were able to return to their original work without discomfort or disability.

Of the four cases of non-union, one occurred in a boy of not very high intelligence, who removed his plaster and went back to heavy work using his wrist within three weeks of his operation. He reported a year later, with the graft fractured and complete non-union of his navicular. Roentgenograms of this patient's wrist could not be obtained.

The next case of non-union was in a patient in whom the graft had not been placed sufficiently far across the fracture line and into the proximal fragment to provide the conditions already enumerated. This resulted in non-union. The patient was operated upon at a later date, another graft was placed across this area, and solid union occurred with a good functional result in the wrist.

The third patient had had an amputation of one arm, and had a fracture with non-

union of the navicular in his remaining arm. Unfortunately, fairly marked arthritis was present in the wrist joint. Aseptic necrosis of the proximal fragment, with marked cystic degeneration, extended widely from the fracture surfaces of both fragments. Under ordinary circumstances, this bone would be considered unsuitable for grafting. Since the patient had only one hand, however, it was thought that an attempt should be made to improve the function of his wrist. For that reason, the operation was undertaken. Eventually non-union resulted. It is possible that, throughout his convalescence, the patient used this hand for all the necessary functions of life, and his thumb and the remainder of his hand and wrist may not have been given the necessary rest period for solidification of the fracture. Ultimately the navicular was excised, because of the pain and disability in the wrist.

The fourth patient had lack of apposition of the fragments.

The contra-indications for operation for non-union of the navicular are as follows:

1. Practically all early fractures, if splinted adequately, will unite, so that bone-grafting for recent fractures is not a necessity.

2. In fractures in which the non-union has existed for such a length of time that there is arthritis in the wrist, disappearance of the articular cartilage between the navicular and the radius, or elongation of the styloid process of the radius, grafting should not be done because, even though the bone should unite solidly, the disability due to the arthritis in the wrist will not be corrected.

The presence of aseptic necrosis of the proximal fragment is not a contra-indication, but is an absolute indication, for bone-grafting, provided generalized arthritic changes are not present in the wrist. With grafting, the devitalized fragment becomes revascularized and the fracture unites in most cases.

One essential reason for doing a bone graft in non-union of fracture of the navicular is that, if the non-union continues for a long period of time, arthritis of the wrist joint develops. This is a bad permanent disability which, when it has reached a late stage, can be overcome and the disability lessened only by an arthrodesis of the wrist. The fact that there are people with non-union of the navicular who say that they have no disability and that they use their wrists actively is no proof that, as further time elapses, arthritis will not develop in the wrist, with consequent disability. The fact that these fractures will unite, and that the navicular bones will remain healthy and continue to function for as long as sixteen years, is adequate evidence that this is a good standard procedure; and, if the rules are followed carefully, good results can be expected.

CONCLUSIONS

1. Of 100 cases of bone-grafting for non-union of the carpal navicular, bony union was obtained in ninety-six. The functional results were excellent.

2. The grafted navicular had a healthy appearance by roentgenogram as long as sixteen years after the operation.

1. Murray, Gordon: Bone-Graft for Non-Union of the Carpal Scaphoid. British J. Surg., 22: 63-68, 1934-35.

DISCUSSION

Dr. Robert I. Harris, Toronto, Ontario, Canada: As a colleague and friend of Gordon Murray, and one who has been intimately associated with him in fracture work in the General Hospital, I have followed with interest the inception and development of his idea of treating non-union of the carpal navicular by bone-grafting. Perhaps the most suitable contribution I can make to this discussion is to state that the operation is of value and the results are good.

I should like to emphasize a point which Dr. Murray made,—namely, that it is necessary to exercise selection in the cases in which bone-grafting is to be undertaken. If displacement of the fragments is of long standing and if there are arthritic changes, the results will not be entirely satisfactory even though union is secured, because the patient is still left with an osteo-arthritis, resulting from the fracture into

the articular surface. Irregularity of the articular surface remains, and this will produce disability in spite of union of the fragments.

An interesting and valuable item in the improvement in our management of fractures of the carpal navicular, which has come from Dr. Murray's contribution, has been the attention we now pay to the fresh fracture. The value of this has been accentuated by the experience gained in the Canadian Army, where facilities existed for developing a policy in the management of injuries to the wrist, influenced by a knowledge of fracture of the carpal navicular. It was easy to demonstrate, as I know it has been in the American Army, that this is a common fracture in the young male, and that it is frequently overlooked and misdiagnosed as a sprain. Only if we appreciate that this is a common fracture, which may not present obvious evidence of fracture, will we be alert and insist upon the use of roentgenograms for injuries of the wrist.

A word as to the management of the late cases which are still painful because of osteo-arthritis: In my experience, arthrodesis of the wrist joint gives the best result, particularly if the patient has to use his hand for heavy work.

Dr. Edwin F. Cave, Boston, Massachusetts: I am very glad indeed to have heard Dr. Murray read his paper on bone grafts for non-union of the carpal navicular. He has just reminded me that he read a paper before this Association on the same subject, twelve years ago. At that time he had a much smaller group of cases, but now I feel quite certain that his series is larger than any which has been followed with end-result studies.

I am a firm believer in the operation; but feel, as does Dr. Murray, that our cases should be selected carefully. Certainly the graft should not be introduced if there is arthritis to any degree, because, even though union of the fragments might be produced, symptoms in the wrist will continue. Also, I doubt the wisdom of attempting to graft in cases of fracture with a very small proximal fragment, which appears dead by roentgenogram. Possibly this type of case would be treated best either by excision of the small proximal fragment, or by grafting the navicular to the lunate bone. Grafting the carpal navicular is not an easy procedure, and it should not be undertaken by a surgeon who does not have a thorough knowledge of the anatomy of the carpus. He should be able to interpret roentgenograms of the carpus taken in various positions,—namely, anteroposterior in ulnar deviation, anteroposterior with the fist closed, oblique views, and lateral views. Roentgenograms of the normal wrist should always be taken for comparison. It is generally agreed that, if fractures of the navicular are diagnosed and treated early with prolonged immobilization, union can be expected in a high percentage of the cases. If at the end of four months, however, there is not evidence of bony union by roentgenogram, then I believe that the graft should be undertaken. Also, in cases which have not been diagnosed early and which have been neglected, grafting should probably be done, rather than immobilizing without the graft.

A few words about the technique of the operation: We have used the curved radial approach, and have inserted the drill and graft under roentgenographic control. We do not use the fluoroscope. To date we have used the tibia as the source of the graft and have removed the graft with the motor saw, taking the full thickness of the cortex, approximately three-eighths of an inch wide and four and one-half inches long. The end of this graft can be shaped to the proper size, and it can be held by the larger end as it is inserted into the navicular. Finally, it is cut off with a rongeur.

Dr. Murray is to be congratulated on his excellent operative results in a large series of cases. I doubt if anyone else can report 96 per cent. of bony union.

AN OPERATION FOR NON-UNION OF FRACTURES OF THE CARPAL NAVICULAR

BY MILTON C. COBEY, M.D., WASHINGTON, D. C.,
AND RICHARD K. WHITE, M.D., PHILADELPHIA, PENNSYLVANIA

From the relative increase in the number of discussions on fractures of the carpal navicular reported in the literature, it may readily be presumed that there is an increase in the frequency of recognition of this fracture. This is predominantly borne out in military life, where one is apt to find a direct reversal of the usual ratio of ten Colles's fractures to one navicular fracture. This has been explained on the basis that an active young man has a strong supporting musculature, which prevents hyperextension of the wrist. The mechanism of this fracture can be justified on the following hypothesis: When hyperextension is prevented, the force is transmitted upward from the palm of the hand; the navicular is then jammed between the capitate bone and the radius. This force on the carpal navicular is one of compression and torsion at the waist. The concave surface of the navicular receives the capitate bone like a wedge, and this wedge action breaks the navicular when exerted at its point of maximum concavity, which is at the waist.

Snodgrass has presented an important physio-anatomical solution to this problem by outlining the following three causes for frequency of fracture of the carpal navicular: ". . . first, it is thinnest in its middle; secondly, the cortex, which is the only hard bone found in any of the carpals (the interior being cancellous), is perforated by small vessels in this area; and thirdly, the scaphoid is the largest and longest bone in the proximal row, and is not segmented, and therefore is less able than the osseous elements on the ulnar side of the wrist to withstand a fracturing force". As a fourth factor, the mechanism of hyperextension must be added. The fact that the navicular forms part of both the distal and proximal carpal rows, plus many other unknown mechanisms of force, may add to the frequency of the fracture in military service. Fractures of the tubercle are extra-articular in relation to the carpus and are of the avulsion type, caused by excessive stress placed upon the radial collateral ligament, which is attached to it.

Properly regulated methods of recognition and immobilization of fresh fractures, or peg-grafting for non-union, will usually produce union. Many fractures of the navicular are not found at first examination, due either to faulty roentgenographic technique, which fails to show a hairline type of fracture, or to the fact that the fracture line itself is not visible. However, the fracture may be seen within ten days to two weeks after the initial injury, with a check roentgenogram. This delayed appearance of the fracture line is explained on the basis of a lowered pH in the local tissue fluid. When there is a relative increase in the hydrogen-ion concentration, the solubility of the calcium salts is increased, resulting in absorption of calcium salts at the fracture site with a subsequent widening of the fracture line[2]. The fracture then becomes visible on the roentgenogram. All sprained wrists should be considered fractures of the carpal navicular until proved otherwise. Clinically the diagnosis may be suggested by a history of a fall on the hyperextended palm, by tenderness in the anatomical or king's snuffbox, by limitation of flexion, and by aggravation of the pain with ulnar deviation. The absolute diagnosis is based purely upon roentgenographic evidence.

METHODS OF TREATMENT

The medical literature indicates a progressive change in the treatment of these fractures. At first a cock-up splint was applied for ten days, followed by massage and electrotherapy for four or five days. Motion was then started; and if after four or five weeks no union had occurred, the carpal navicular was removed. Since then the treatment has

consisted either of resection of one or both fragments, of the proximal row of carpal bones with the proximal fragment, or of the entire navicular; arthrodesis of the joint; and, more recently, immobilization in plaster-of-Paris for as long as twenty-four months. Efforts to obtain bony union surgically have included the use of onlay grafts, multiple drilling of the fragments, a single large peg graft, and, finally, the present method of multiple peg grafts. The authors feel that the prolonged use of plaster-of-Paris casts not only involves some occupational and economic interference, but also produces decalcification and osteoporosis of the bones of the forearm, wrist, and hand; this is more than a simple disuse atrophy, as suggested by Watson-Jones and Roberts.

The shortest period of immobilization which is commensurate with bony union would seem to be the treatment of choice. Although it is sometimes difficult to evaluate symptoms, the authors believe that ununited fractures are painful. The period of immobilization need not be unduly long, if the fractures are recognized early and are adequately immobilized. The authors had used for years the method which Thorndike and Garrey described in 1940 and called the "standard" method of immobilization of fresh fractures. The wrist is immobilized by a cast in 50 degrees of extension and slight radial deviation, with the thumb included in the cast to the interphalangeal joint. To this may be added the necessity of firmly locking the fragments by wide abduction of the thumb, which increases the radial deviation. This method is similar to the one advocated by Ritter.

It has been the authors' policy to immobilize the fracture by the method outlined for a period of six weeks. At the end of this time the cast is removed, and a roentgenogram is taken. If trabeculation across the fracture site is not complete, another cast is applied for two weeks. By the end of this time, union usually has taken place. Operative procedures are not considered until a full trial of immobilization has been given. If the fracture has not healed at the end of the eight-week period, the immobilization is continued for a total of twelve weeks.

Bone-grafting has been done only on those patients who had fresh fractures which did not heal. No fracture was considered amenable to grafting which was older than one year. The criteria of non-union are based upon roentgenographic findings alone. Roentgenographic evidence of non-union consists of sclerosis and eburnation of the bone at the fracture line with no evidence of trabeculation, and of bone absorption with a gap at the fracture site after a lapse of time which would normally be sufficient to permit healing. Fractures which show cystic changes in either fragment are not considered suitable for operation.

OPERATIVE PROCEDURE

The first bone-graft operation for fracture of the carpal navicular in this country was done by Adams and Leonard in 1928. Until 1934, however, the method had not come into general use. During this period it was recommended for non-union and pseudarthrosis. Autogenous bone grafts were taken from the tibia. Results following bone grafts were reported as uniformly good.

The procedure employed by the authors, which has been found to be generally successful, is as follows:

A dorsal longitudinal incision is made on the lateral side of the extensor pollicis longus tendon and is carried distally to the extensor crease of the wrist, which is followed transversely to the mid-point of the wrist (Fig. 1). It is necessary to recognize and avoid the superficial branch of the radial nerve. The description of the dissection which follows is made with the hand in the anatomical position of supination. Actually the hand is placed across the chest at operation. The extensor indicis proprius tendon is retracted medially with its tendon sheath. The other extensor tendons are retracted with this tendon, except the extensor pollicis longus tendon, which is retracted laterally. The dorsal carpal ligament is incised longitudinally, thus allowing for exposure of the capsule of the wrist di-

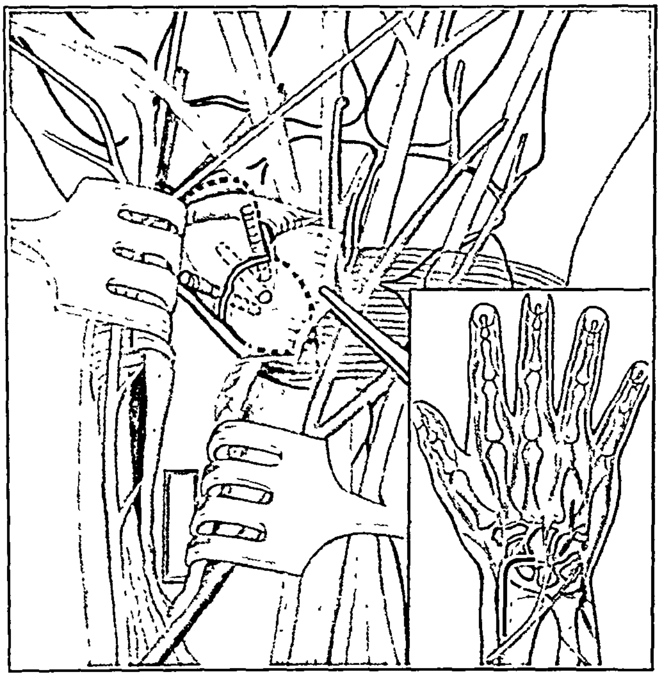


FIG. 1

Drawing of the operative procedure of triple-peg grafting of the carpal navicular. Shows the donor site and the three pegs in place. Inset demonstrates the type of skin incision which produces the least scar.

rectly over the navicular. The dorsal radiocarpal ligament and capsule are incised longitudinally, and sufficient room is thereby allowed to expose the bone with gentle retraction for almost its entire dorsal aspect. It is sometimes necessary, for better exposure, to move the tendon of the extensor carpi radialis brevis from its groove in the end of the radius and to retract it laterally. No harm has been seen to occur as a result of this retraction. Since the longitudinal portion of the primary incision of the skin is eight centimeters long, there is plenty of room to remove a bone graft from the distal quarter of the radius without including the metaphyseal end of the bone or disturbing the radiocarpal ligament. The fracture of the navicular is exposed; any intervening ligamentous or fibrous tissue is removed by sharp dissection, bone rasp, or curette; and the bone edges are fitted together. Three drill holes are then carried across from one fragment into the other fragment, leaving each bit in place. By leaving these three drill bits in place, the fracture is maintained in accurate position. Since one bit is removed at a time, and replaced by a bone peg, the driving of the pegs will not displace or separate the fragments, because the drills are placed at three different angles and pin the fragments tightly and firmly together. The proximal end of the incision is retracted laterally with the extensor pollicis longus and other extensor tendons, which is approximately at their musculotendinous junctions. The tendons of the extensor pollicis brevis, the abductor pollicis longus, and the extensor carpi radialis brevis are retracted medially. The distal fourth of the radius is now exposed, and the periosteum is elevated as far as the metaphysis. A graft of good cortical bone, one-half inch wide and one inch long, is removed. This large graft is split longitudinally to make three square

TABLE I

RESULTS IN NINETY CASES OF FRACTURE OF THE CARPAL NAVICULAR

	Number	Average Period of Immobilization (*Weeks*)	Union	Non-Union	Grafted	Disposition of Cases		
						Full Military Duty**	Restricted Military Duty**	Certificate of Disability Discharge
Fresh fractures	51*	7.4	45	2	2	46	0	0
Untreated fractures	39	0	0	39	10	16	18	5

* Five patients are still under treatment.
** Follow-up after six to eighteen months.

TABLE II

RESULTS IN CASES OPERATED UPON

	Number	Average Period of Immobilization (*Weeks*)	Union	Patients Discharged to:	
				Full Military Duty**	Restricted Military Duty**
Fresh fractures	2	9.6	2	2	0
Untreated fractures	10*	9.6	7	7	1

* Three patients are still under treatment.
** Follow-up after six to eighteen months.

peg grafts, one-eighth inch in diameter, which is the size of the drill bit. The drill bits are then removed one at a time and each is replaced by a peg graft, which is driven through to fix both fragments. After the drills have been removed and all grafts have been inserted, the wound is closed simply by suturing the capsule and then the dorsal transverse carpal ligament. All tendons fall nicely into place. The subcutaneous tissue and the skin are closed in layers. A cast is applied, similar to that used for a fresh fracture. This cast is removed at the end of six weeks and a roentgenogram is taken. The condition of the bones and the amount of union are checked, and, if union has not taken place, another cast is applied for three weeks. At the end of this time another check is made by roentgenogram, and either a cock-up splint or another cast is applied, depending upon the amount of healing. After union is complete, active motion, graduated exercises, and special wrist movements are combined with physical therapy to restore the normal range of motion and strength.

CLINICAL DATA

From March 1942 to August 1945, ninety cases of fracture of the carpal navicular have been treated. Of these, fifty-one were fresh fractures, treated either in the Orthopaedic Clinic or in the hospital (Table I). The average time required for union of these fresh fractures was 7.4 weeks; non-union was present in two cases. In these patients, grafting was subsequently done by the multiple-peg method, and bony union resulted. As might be expected, the fractures which took the longest time to heal were those through the waist or the proximal portion of the navicular. Those which were near the distal portion of the bone usually healed within six weeks. The patients returned to full duty with a painless, functioning wrist joint. A follow-up study was carried out on the soldiers who had had fresh fractures of the navicular, by writing to their respective commanding officers regarding postoperative care. The reports were made from six months to three years after the men had been discharged from further treatment. Reports were received concerning 62 per cent. of the patients with fresh fractures, and all were on full military duty, many of them overseas. Of the postoperative cases, follow-up studies showed all except one to be on full duty.

Thirty-nine old cases of non-union, which had had no previous treatment, were seen. The period of disability after the initial injury ranged from five months to eighteen years. It was always difficult to determine the amount of disability which resulted from non-union, and in every case the symptomatic findings were the guiding factors. Eighteen patients were placed on restricted duty, sixteen returned to full duty, and five were discharged from the Service with a Certificate of Disability Discharge because of complaints concerning the wrist. Ten of these patients were suitable for bone-graft operations. Of those who were placed on restricted duty, two had associated fractures of the lunate bone

and the first metacarpal, respectively. Another patient had an associated low-back pain, which necessitated placing him on limited service.

The twelve patients upon whom bone-graft operations were performed (Table II) had had recent fractures with definite evidence of non-union. The fracture lines were clearly defined at operation. The amount of mobility of the fragments seemed to depend upon the width of the fibrous tissue filling the gap. Either bone-end absorption or wider separation of the fragments in the first place resulted in more fibrous-tissue replacement. The authors believe that union in these operated cases would not have occurred after even two years of immobilization, because of the mobility, the width of the fibrous-tissue gap requiring replacement with bone, and the sclerosis of the fractured bone ends. The fibrous tissue did not have the appearance of preosseous tissue. After it had been excised and the sclerotic ends had been removed with a very small rasp or curette, even though actual bleeding of the bone surfaces was not evident, the bone appeared more nearly normal in texture. The average period of immobilization after operation was 9.6 weeks. In a few instances it was necessary to continue a cock-up splint for three or four weeks to ensure full bony union. Some illustrative case reports follow.

CASE 1. This soldier sustained a fracture of the navicular in May 1944. It was adequately immobilized for a period of eight weeks Because absorption between the fragments of the fracture had taken place, it was decided that non-union would eventually result, and bone-grafting was therefore done The cast was removed after eight weeks, and firm bony union was established by roentgenogram The patient was discharged after rehabilitation, with a normal range of motion and complete function of the wrist (Figs 2-A and 2-B).

CASE 2 This patient sustained a fracture of the carpal navicular in February 1944 No cast was applied. There was definite roentgenographic evidence of non-union A grafting procedure with multiple pegs was done in July The patient was discharged to full duty in November 1944 with complete bony union and full function of the wrist (Figs 3-A and 3-B)

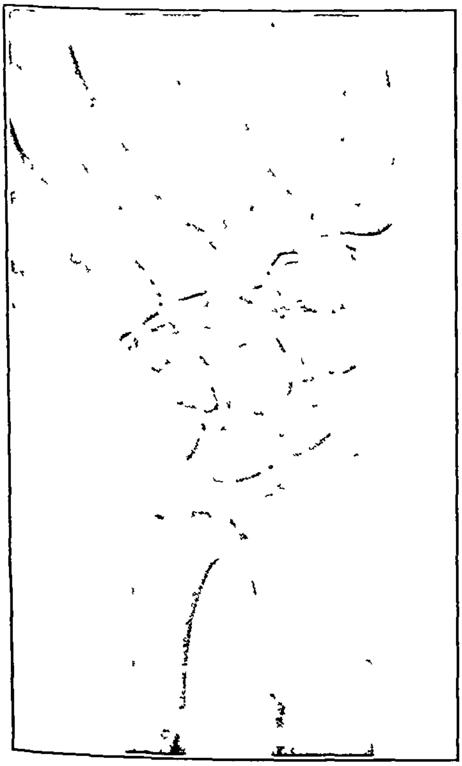


FIG 2-A

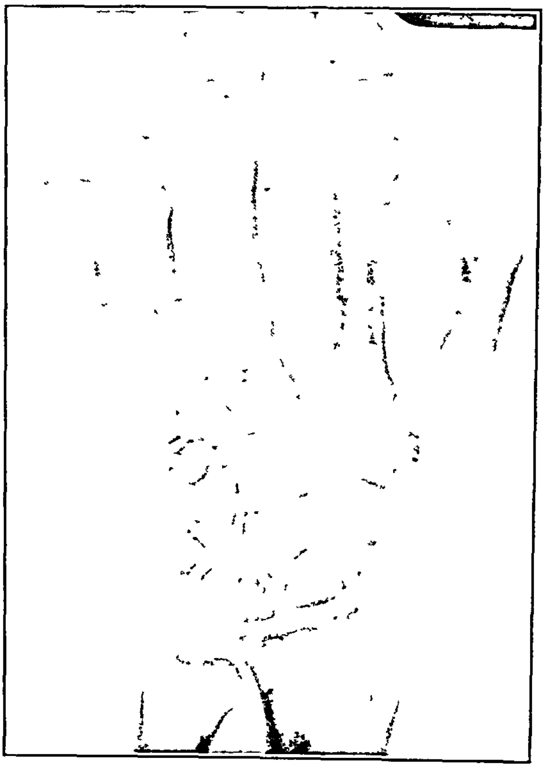


FIG 2-B

Fig 2-A: Case 1 Non-union of carpal navicular Marked separation of fragments can be seen.
Fig 2-B: Same patient after triple-peg bone-graft operation

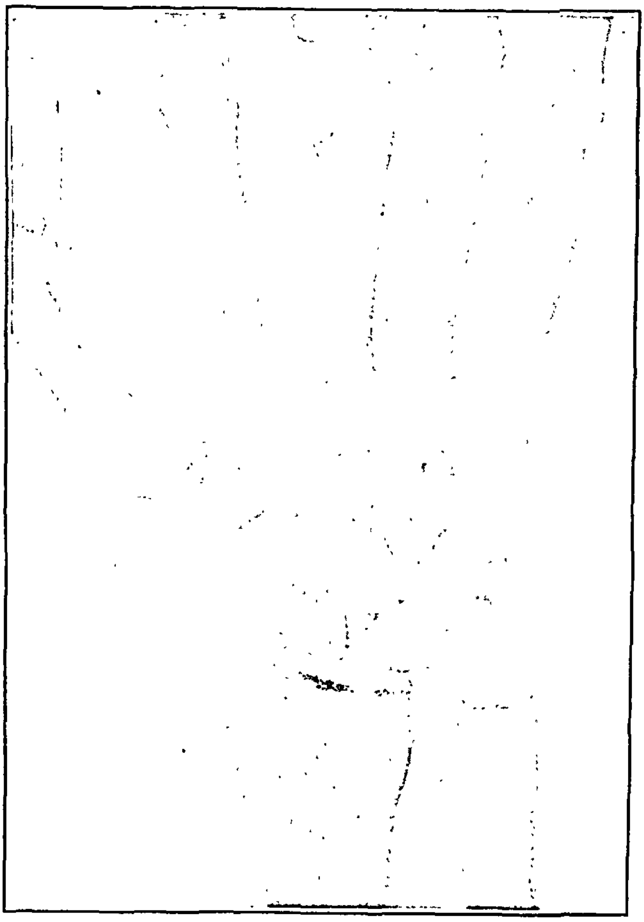


Fig. 3-A

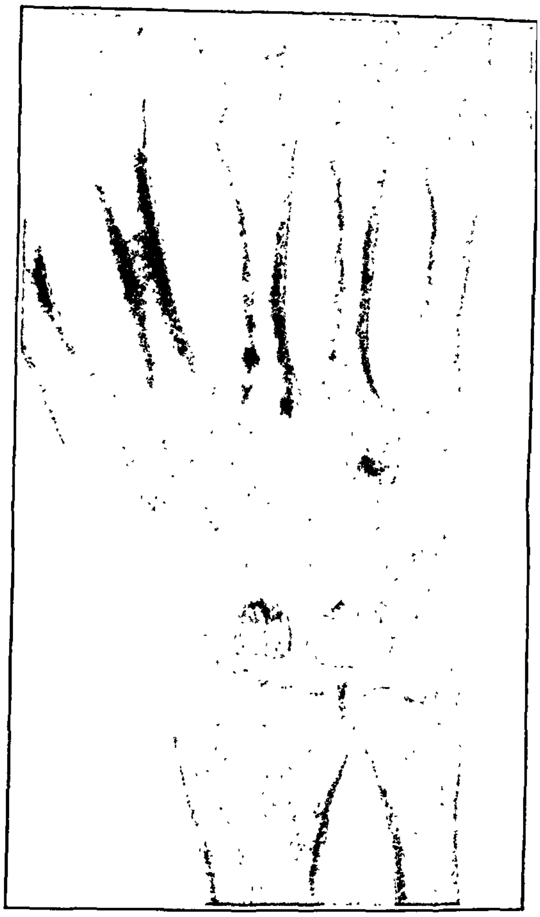


Fig. 3-B

Fig. 3-A: Case 2. Non-union before triple-peg bone-graft operation.
Fig. 3-B: Position of grafts after union can be made out.

Fig. 4-A

Fig. 4-B

Fig. 4-A: Case 3. Non-union before triple-peg bone-graft operation. Fragments are widely separated. Fig. 4-B: Complete bony union.

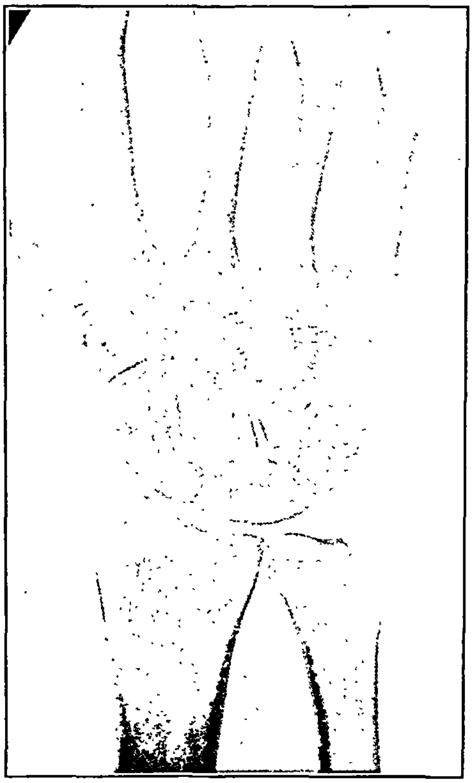
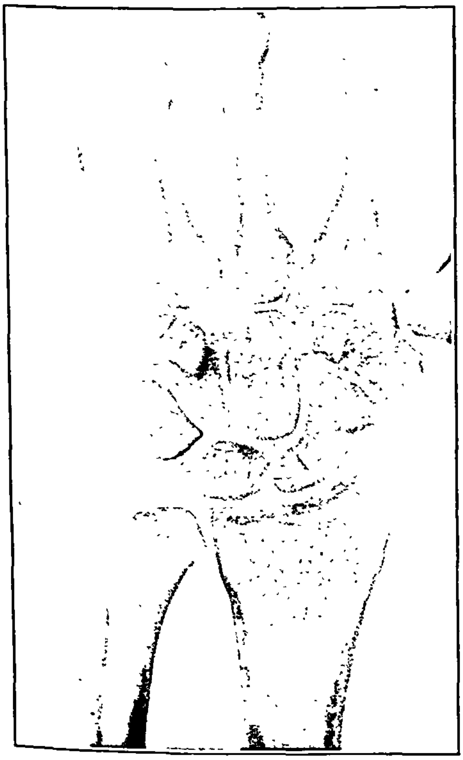


FIG. 5-A FIG. 5-B

Fig. 5-A: Case 4. Fracture of waist of carpal navicular, with angulation of fragments and non-union.
Fig. 5-B: After triple-peg bone-graft operation.



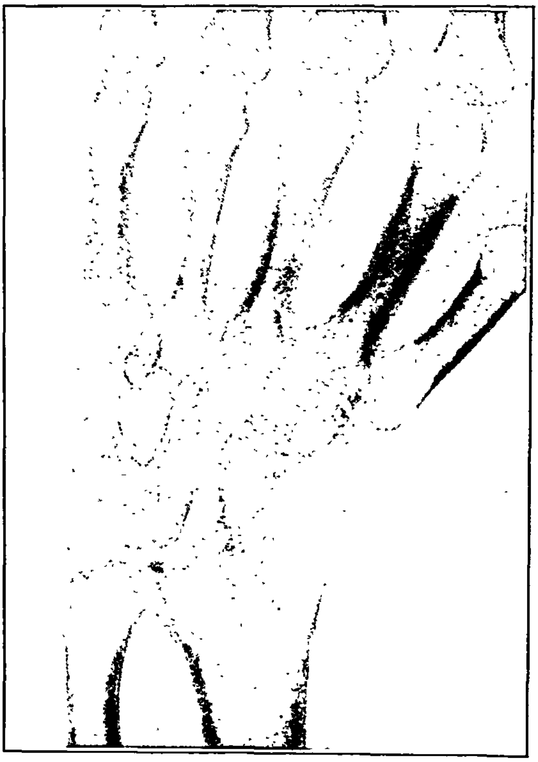


FIG. 6-A FIG. 6-B

Fig. 6-A: Case 5. Shows non-union near proximal end of navicular.
Fig. 6-B: After triple-peg bone-graft operation.

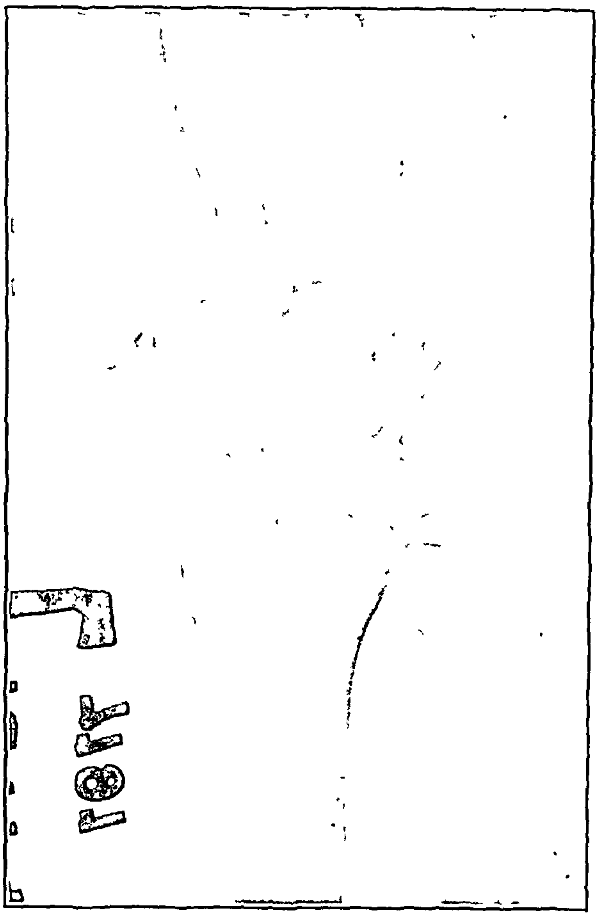


FIG. 7

Case 6. Non-union after onlay bone graft and multiple drilling across the fracture site; peg graft was not used to bridge the fragments.

CASE 3. Fracture of the carpal navicular was incurred during military activity in October 1943. Non-union was established when the patient was seen in the Orthopaedic Clinic in June 1944. The soldier was operated upon in June. After operation he wore a cast for nine weeks and a splint for four weeks. He was discharged to full duty in October 1944, after bony union had been established; he had full function of the wrist and no pain (Figs. 4-A and 4-B).

CASE 4. The initial injury to the wrist occurred in July 1944. The patient received no medical treatment and a cast was not applied. Bone-grafting was done in September 1944. A plaster-of-Paris cast was necessary for twelve weeks, and the patient wore a splint for an additional three weeks. He was discharged to full duty in January 1945, with a completely healed wrist (Figs. 5-A and 5-B).

CASE 5. Bone-grafting of the carpal navicular was done on this patient five months after his initial injury. The cast was removed for the last time after ten weeks of immobilization; for part of this time he had been treated on an ambulatory basis. Due to lack of cooperation on the part of the patient in following the program of graduated exercises, there was some residual stiffness of the wrist, despite re-admission for the purpose of convalescence. This was the only patient in the series of cases which came to operation who was placed on restricted duty. It was felt definitely that this man would have had just as good a result as the others, if he had cooperated properly (Figs. 6-A and 6-B).

CASE 6. The patient was admitted to the hospital for bone-grafting in August 1942, after an injury to his left wrist. This was the second injury to this wrist; the patient gave a history of previous injury in 1938, while playing baseball. As this was the first operative case in the Service, it is presented to show the development of the method of grafting with three pegs. This patient had had multiple drill holes and one large onlay graft. He wore a cast for ten weeks, but no union occurred. Clinical fibrous union was present; but the authors felt that, if three pegs had been inserted into the three empty drill holes across the fracture, union might have occurred. Because of the experience with this case, the three pegs were used thereafter. Clinically, however, this patient had excellent function of the wrist with no complaints of pain. He was discharged from the hospital to full duty, and has been serving in the Armed Forces in that capacity ever since (Fig. 7).

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THE CONSERVATIVE TREATMENT OF CONGENITAL TALIPES EQUINOVARUS

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The medical literature is replete with hypothetical considerations of the etiology of this common congenital anomaly, but actually nothing new has been added since Hippocrates's description and discussion of congenital club-foot. The treatment since the days of Hippocrates had not materially changed until the *redressement forcé* was begun many years later. The modifications that followed were as numerous as the number of orthopaedic clinics the world over.

In his first paper in 1930, Kite himself disclaimed any originality for his method of treatment, stating that it was "as old as the science of medicine". Taylor, in 1892, reported his successful treatment of club-foot by what he called continuous leverage and retention in a cast. This was simply a method of treatment by a corrective cast, although without the refinement of wedges to help in the correction.

In this same year English orthopaedic surgeons began using metal splints in the treatment of club-foot. These, too, were modified many times in successive years, and in 1937 Denis Browne reported a new modification of this splint, the twelfth of its line; at that time he stated that the splint works on the mechanical principle that it is possible to correct the position of one foot by means of the other. In 1940 and 1941 a new modification of this splint was introduced in the United States.

Brockman, whose book on club-foot has become a classic, in a more recent paper about treatment of this condition, says: "After a long experience of the method of treatment upon which I was brought up—namely, repeated forcible manipulation of the deformed foot and fixation of the foot in the corrected position with plaster strapping—I have come to the conclusion that it is a poor method in every way when compared with the one advocated by Mr. Denis Browne."

Today, in considering any kind of treatment, it is necessary to pay attention to all the components of the deformity in order to make of the congenitally deformed foot one that is the exact opposite,—a hypercorrected foot.

The deformations are essentially three: adduction, inversion. and equinus. The adduction is located in the fore part of the foot and may be considered as an angulation between the fore part and the hind part of the foot, which takes place mainly in the mid-tarsal joint.

Peabody and Muro believe that it is necessary to differentiate the metatarsus varus component of talipes equinovarus from true metatarsus adductus,—a different entity without real changes in the position of the posterior part of the foot. The metatarsus adductus is, in their opinion, easily corrected; the metatarsus varus, generally with deformation of the metatarsal bones and cuneiforms, is very hard to correct.

The inversion takes place in almost the entire foot, but mainly in the subtalar joint; the talus is fitted into the mortise of the ankle joint, and the calcaneus in supination is rotated inward under the talus. The equinus deformity takes place, first, in the ankle joint, which is in plantar flexion and may be called "ankle equinus"; second, there is also the equinus of the fore part of the foot in relation to the posterior portion, called "forefoot equinus" or cavus, taking place in the mid-tarsal joint.

Any attempt to get a good correction of the club foot must accomplish the correction

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of all these deformities in sequence: adduction, inversion, equinus of the fore part of the foot, and equinus of the ankle joint.

First of all, the adduction of the fore part of the foot must be corrected in order that the navicular, which was medial to the head of the talus, be drawn in front of the head of that bone. This apparently simple deformation, perhaps the least important of any of them, sometimes is hard to correct, and gives the foot a characteristic appearance, with varying degrees of "toeing in".

Kite says that in the adduction deformity, if the navicular is still on the medial side of the head of the talus when the treatment is discontinued and the child is allowed to walk, the weight thrust will fall obliquely on the side of the navicular and will push the fore part of the foot back into the adducted position. If the fore part of the foot is carried outward too far, the navicular may be drawn around lateral to the head of the talus into a flat-foot position, which is undesirable. Care should be exercised to correct the adduction deformity completely, without overcorrecting it.

FIG. 1
"Rocker-bottom" deformity in a patient treated with the Denis Browne splint.

In the inversion or varus deformity, the calcaneus appears to be supinated under the talus, which is attached firmly into the tibiofibular mortise. *This is the next deformity* to be corrected. The third deformity to be corrected is the plantar flexion or equinus in the mid-tarsal joint. The last deformity is the equinus in the ankle joint, and no attempt should be made to correct it until the three other deformations have been corrected. This is of paramount importance since, with the foot in the equinus position, the subtalar joint is relaxed and it is easier to correct the adduction and varus deformities. When attempts are made to correct the equinus deformity without previous correction of the supination and adduction, the calcaneus will remain in the position of equinus and supination. The fore part of the foot is forced into dorsiflexion; and a converse deformity in the mid-tarsal joint develops, which is recognized clinically and roentgenographically as the "rocker-bottom" foot (Fig. 1).

The treatment of the club foot must be checked periodically by clinical observation and by roentgenograms. The anteroposterior films give a clear view of the deformation *of the fore part of the foot against the deformations (adduction and inversion)* of the posterior part of the foot; the lateral views show the equinus position in both the mid-tarsal and ankle joints.

The deformation of the fore part of the foot is checked by comparison of the alignment of the metatarsals with that of the tarsal bones. Kite believes that adduction of the fore part of the foot has not been corrected when the mid-line of the talus points toward the little toe instead of toward the great toe.

As the center of ossification of the navicular does not appear until the fourth year, this bone is not seen in roentgenograms taken before this age; until then the coincidence of the mid-line of the talus and the first metatarsal segment is used.

Normally, the calcaneus and the talus are fitted in such a way that the calcaneus articulates with the cuboid on the lateral border of the foot, and the talus articulates with the navicular on the medial border; both bones appear in the anteroposterior roentgenograms, forming an angulation of from 30 to 35 degrees. In the varus deformity the calcaneus is supinated,—that is, rolled under the talus, decreasing this angle. As the object

of treatment of the varus deformity is to pronate the calcaneus, the evidence of its accomplishment will be the separation of the anterior ends of both bones, as specified before.

When the equinus position is not corrected, the lateral roentgenograms will show the talus extending over the calcaneus by half its length; at the end of successful treatment, the anterior ends of both bones are more or less in the same transverse plane.

In the past, the treatment of club-foot in this Orthopaedic Department followed one of three methods: (1) initial treatment by frequent changes of casts; (2) attempts to attain full correction at one sitting by means of a wrenching and lengthening of the tendo calcaneus under anaesthesia; and (3) initial treatment by manipulation under gas anaesthesia.

For the last few years some changes have been made, and at present the treatment falls into one of the following categories, depending upon the age of the patient when first seen:

1. Splints.
2. A wedged cast, or the Kite method.
3. Manipulation under anaesthesia, with some restrictions.

With a clear understanding of what a club foot is and what procedures are necessary in order to correct the deformations, an analysis will be made of the three principal conservative methods of treatment which are being used in this Clinic, and their limitations will be discussed.

1. *The Denis Browne Splint in the Treatment of Congenital Club-Foot*

Brockman's opinion of the splint has already been stated. In 1941, Stuart Thomson of Toronto introduced the splint into the United States. He stated that the results of treatment with older methods were discouraging, while in sixty cases of equinovarus deformity treated by him with the Denis Browne splint, there was only one recurrence (blamed entirely upon the mother).

Van Domselaar, of Buenos Aires, presented in 1943 a report based upon his experience at the Campbell Clinic in Memphis, Tennessee. Of twenty-eight cases treated by means of the Denis Browne splint, there were twenty-six cases with excellent correction and two failures (one because of intolerance to adhesive strapping, and the other due to multiple deformities and lack of cooperation of the parents). Correction was obtained in from four to eight weeks, except in one case (treated previously with manipulation and casts) which took nine weeks. His report is very optimistic, but the follow-up of the cases is insufficient.

A paper by Jergesen in the same year, on unilateral club-foot treated by the Denis Browne splint, and another by Bell and Grice in 1944, bring the bibliography on the subject up to date. Many minor modifications of the original splint have been made, and most of the details have already been described.

In the Orthopaedic Department of the University of Iowa Hospitals, a type of plate is employed which is similar to that used by Bell and Grice; it is made in three different sizes, according to the size and age of the child. Lately, since more attention is being paid to adduction of the fore part of the foot, the shape of the plates has been changed so as to make them curve outward, with a concave lateral border and a convex medial border. A special device is placed under the plates, to allow rotation of the plate on the bar.

The horizontal bar is flat, and does not differ from that described by other authors. The plates are covered with felt instead of rubber sponge; this is stuck on the surface of the plate, facing the foot. The technique of strapping follows more or less the plan generally used. It is, of course, necessary to keep certain principles in mind to assure success by this method:

1. There must be perfect apposition and attachment of the foot to the plate.
2. In order to prevent oedema, no windows should be permitted between the strips.
3. There must be no wrinkles, to avoid excoriation of the skin.
4. The skin must be clean, and must be prepared by washing with tincture of benzoin.

Since more attention has been paid to the correction of the adduction of the fore part of the foot, the authors have adopted Bell and Grice's technique in applying the first two strips. In the bilateral cases, both feet are bound to the plates according to this technique. In the unilateral cases, the normal foot may be strapped in a similar manner, but it is not necessary to follow a special technique; it is enough to have the normal foot firmly flat on the plate.

It is better to begin by holding the foot or feet on the plates for a short while in the position of deformity,—that is, not to attempt immediate correction of the adduction, inversion, and equinus. With this idea in mind, the bar is bent to the shape of an inverted V and applied to the plates without changing the position of the foot. This has some advantages: The flexibility of the foot is increased; there is no swelling; dermatitis is minimized; and the foot always remains soft, which greatly facilitates the treatment.

At first the strapping is changed every five to eight days,—preferably every five days. The authors prefer to keep the patient in the Hospital during the first period of treatment,—that is, from four to eight weeks; then he is discharged, provided there is assurance of proper home care and of prompt return, at stated intervals, for continuation of the treatment.

After two or three sessions, the bar is straightened out, and, as the feet follow the position of the bar, the adduction and inversion become diminished until the neutral position in the anteroposterior plane is obtained. From then on, the foot is gradually rotated and abducted until it reaches 90 degrees of outward rotation. As long as the bar is kept straight, adduction is corrected and inversion is reduced to the neutral position. To change the varus into a valgus deformity, the bar may be bent to assume a true V shape earlier,—that is, starting when the foot points straight forward. The former way—namely, the anteroposterior position with 90 degrees of external rotation on the bar (the so-called "Charlie Chaplin" position)—is the usual procedure.

In subsequent sessions, when adduction and inversion have been corrected, one starts the stretching of the calf muscles. This is done by accentuating the V bend of the bar while the foot is still held in 90 degrees of outward rotation. When the deformity is unilateral, the bar on the normal side is bent horizontally so that the foot is held in a neutral anteroposterior position all the time.

The treatment with the Denis Browne splint is active treatment: The more the baby kicks, the more the correction is improved; when flexion movements at the knees are carried out, the feet go into valgus and the calf muscles are stretched. The active kicking results in marked development of the calf muscles. The progress of correction is checked by roentgenograms, according to the standard criteria mentioned previously.

After the correction of all the deformities has been accomplished, the problem is to maintain this correction. Thomson allots five or six weeks for correction, about five months for use of the splints, and another six months in boots; after the child begins to walk, shoes are used during the day and splints at night,—for years, if necessary.

Bell and Grice do not like the use of shoes attached to the plates, or the use of plaster casts in order to maintain the correction. They advocate the use of the plates with the feet strapped on them for at least a year.

Van Domselaar states that, after correction has been obtained within six or eight weeks, the plates are attached to baby shoes with a small corset stay for the legs. After the child is seven months of age normal shoes, attached to the bar, are used.

In this Clinic the policy is to start the treatment as early as possible; correction was obtained in the favorable cases in about eight weeks. After correction it is advisable to use the plates and bar, as Bell and Grice do, for a long period of time. When the baby is old enough to wear shoes, they are attached to the plates in reverse (the left shoe on the right side and the right shoe on the left side), and the splints are worn twenty-four hours every day. After two to four months the mother is instructed to allow the child to wear the

FIG. 2-A

FIG. 2-B

Show patient before and after treatment with the Denis Browne splint.

FIG 2-C

FIG 2-D

Roentgenograms taken before and after treatment.

splints twenty hours each day, and to be without them the other four hours. When the baby reaches the walking age, a similar program is followed: The splints are worn at night and during napping hours for a long period of time, and shoes with outer patches on the soles are worn for standing and walking. In some instances club-foot plates are placed in the shoes, in addition.

Van Domselaar cites twenty-eight cases; the ages of the patients ranged from three weeks to four and one-half years. Correction was obtained within four to eight weeks. The results were excellent in twenty-six cases; failures occurred in two cases.

Of forty-six cases, Bell and Grice obtained excellent results in eleven, good results in twenty-nine, and fair results in six. They considered an excellent result to mean an essentially normal foot (external rotation with a full range of dorsiflexion and eversion). A good result meant a foot without structural changes, but with some limitation of motion as compared with the normal. A fair result was one in which a mild deformity of one of the elements persisted, but did not cause any appreciable disturbance in gait

This report covers cases treated by the Denis Browne method in the Orthopaedic Department of the University of Iowa Hospitals from 1942 to 1945, inclusive. The cases are divided into two groups: The first group includes patients treated only with Denis Browne splints; the second group includes cases in which treatment was started with Denis Browne splints and completed by other types of conservative treatment.

From February 1942 to November 1945, of 161 cases of congenital club-foot, forty-one were treated from the beginning with Denis Browne splints. In twenty-eight of these cases the deformity was bilateral and in thirteen it was unilateral, giving a total of fifty-nine cases of club-foot.

The age at onset of treatment varied from two weeks to one year; most of the patients (nineteen, or 46.3 per cent.) were between two and six weeks old, eight (19.5 per cent.) were two months old, and 12 (29.3 per cent.) were between three and five months of age,—a total of thirty-nine patients under six months of age. Two patients were over six months of age. Most of the cases, therefore, were treated very early. The period of observation varied between four months and three years.

The results were as follows:

1. Excellent correction of all these components—adduction, inversion, and equinus—was obtained in 21.5 cases, or 53 per cent. (Figs. 2-A, 2-B, 2-C, and 2-D).

2. Correction of the deformity, with but a slight degree of metatarsus adductus remaining, was attained in ten cases, or 24 per cent.

3. More than one of the components of the deformity were still present in 9.5 cases, or 23 per cent. (The figures of 21.5 and 9.5 each include a case in which one foot was corrected and the other was not.)

Of the second group, in which treatment was started with the Denis Browne splint and completed with another form of conservative treatment, full correction was obtained in four cases after treatment of the adduction with Kite casts. In four cases of the same group, wrenching was advised and was refused. One patient has had the Kite cast, without success to date. In one case, correction of the remaining metatarsus adductus with the Denis Browne plate is still being attempted. It is possible that, in some of these cases, wrenching or the Kite casts will be needed to obtain complete correction.

Of the 9.5 cases in which more than one component of the deformity was still present, correction was obtained in five after treatment had been completed with wrenching or the Kite casts.

It is evident that these results with the Denis Browne splint alone are not so optimistic as those published elsewhere. The cases in which success was attained with the Denis Browne splint alone, together with those in which the Denis Browne splint was complemented by another type of conservative treatment, total almost the same as, or more than, those of most of the other authors; only Kite's own results with wedge casts are better. If to the 53 per cent. of excellent results are added the cases with good results after use of the Kite casts or wrenchings in the second and third groups, the total is almost 80 per cent. of good results with conservative treatment.

The better functional results with the Denis Browne splint, alone or complemented with other conservative treatment, are possibly due to the fact that the feet are almost always kept flexible with the use of the splints.

2. *The Kite Cast or Wedged-Cast Method*

We are all familiar with the excellent description given by Kite of the steps in applying the casts and taking the wedges. In this method also, one is concerned with correction of the adduction of the fore part of the foot, then with the varus of the heel and the correction of the cavus, and finally with the correction of the equinus in the ankle joint. It is important that wedgings be made once or twice a week, and that a completely new cast be applied after every three or four wedgings. When all the components have been corrected, the foot should be maintained in the corrected position in a retentive cast for several months. These casts, too, should be changed every few weeks; and at these times the knee and ankle joints should be put through a complete arc of motion. Small wedges taken frequently, without undue strain being put on the joints and their soft structures, may take somewhat longer to attain full correction, but assure a more satisfactory foot, both from the cosmetic and from the more important functional standpoint. Meticulous care in applying the casts and taking the wedges is essential.

Forty-three cases were treated by this method. The ages ranged from seven days to thirteen months at the onset of treatment. Two patients had had retentive casts applied

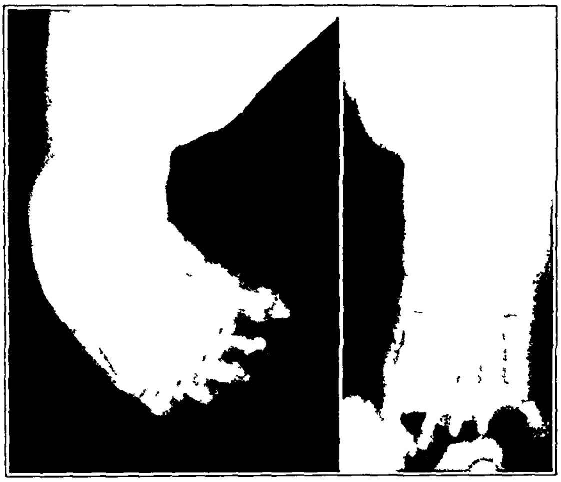

FIG. 3-A

FIG 3-B

Roentgenograms taken before and after treatment by the Kite method.

by local physicians prior to their first admission to this Hospital, but no attempt had been made by the local physicians to obtain any correction. The duration of treatment ranged from two to thirteen months. In eleven cases there were recurrences, which were re-treated with Kite casts. One patient had the Brockman treatment in conjunction with the Kite treatment. Six had lengthenings of the tendo calcaneus to correct residual equinus. In thirty-two cases, or a total of 74.4 per cent., the results were good (Figs. 3-A and 3-B). This does not include the five cases which were first treated by the Denis Browne splint and then by the Kite method. Of these, four had good results and one had a poor result. Eleven cases, or 25 per cent., had poor results. They were later treated by wrenchings and plantar strippings, and will probably eventually come to bone operations. Of these, three were cases of spina bifida.

A comparison of these statistics with those of Kite shows that the authors obtained good results in fewer cases than did Kite.

3. *Manipulative Treatment under Anaesthesia*

Fifty-seven patients (eighty-one feet) were treated exclusively by corrective casts and wrenchings, except for two cases in which Kite casts were used for short periods between

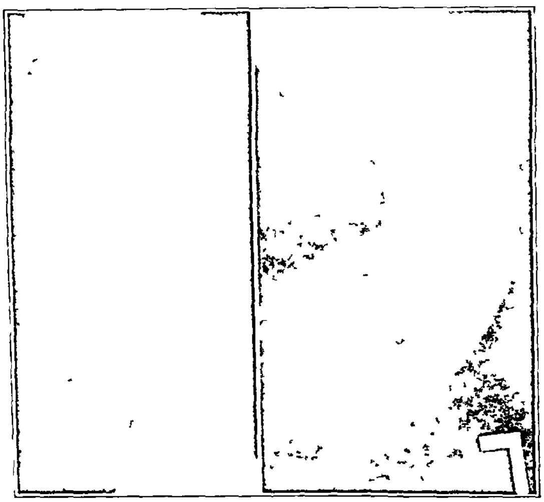

FIG. 4-A

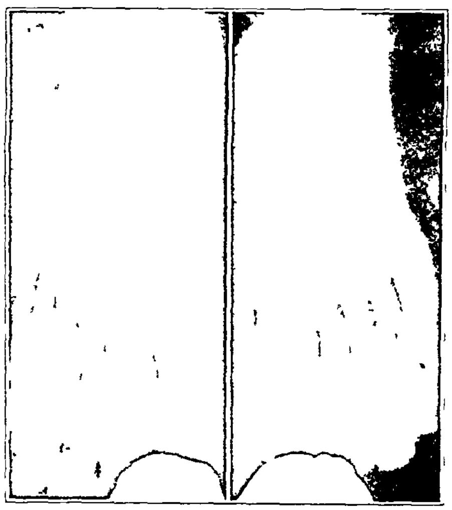

FIG 4-B

Before and after treatment by wrenchings

wrenchings, without improvement. They represent all the cases of club-foot that were treated by manipulation between 1940 and 1942. This period of study was chosen for two reasons: first, to give a sufficient follow-up period for determining late end results; and second, because, after 1942, many of the cases were treated by combinations of wrenchings, Denis Browne splints, and Kite casts. The word "wrenching" is used here to denote forceful manipulation under anaesthesia, without the use of the Thomas wrench and wedged bar.

During this period thirty-six cases, with a total of fifty-four club feet, were treated in the Clinic by the Resident Staff. (Since there were a number of bilateral cases in which one foot required additional operative work to complete the correction, the statistics are given according to the number of feet and not according to the number of cases.) Of this number, correction was complete in ten feet, or approximately 19 per cent., and six feet were corrected except for a slight adduction of the fore part of the foot, giving a total of good results of approximately 30 per cent. (Figs. 4-A and 4-B). Of the sixteen good results, eleven had to have lengthenings of the tendo calcaneus to complete the correction. Five were corrected without such lengthenings. These cases all have roentgenographic evidence of the correction.

In the private cases where the wrenchings were done by Dr. Steindler, the statistics are much better. The basis for correction rests mainly on clinical impression, however, because during the period of study, roentgenograms were taken infrequently on private cases. In most cases, the follow-up has been sufficiently long to show that the correction has been maintained, and in no case where clinical correction had been reported was there found later to be roentgenographic evidence of residual deformity. This is not true of the cases treated in the Clinic, as often clinical impressions have been found to be at great variance with the roentgenographic picture.

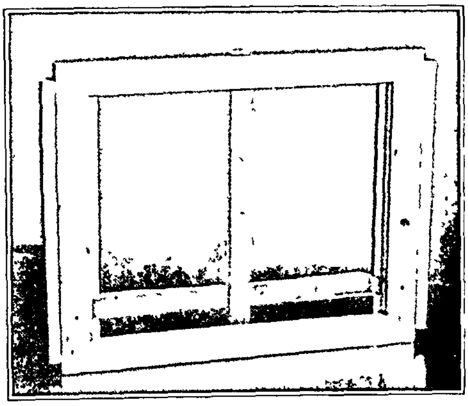

Fig. 5-A

Special cassette holder for the standardization of roentgenograms.

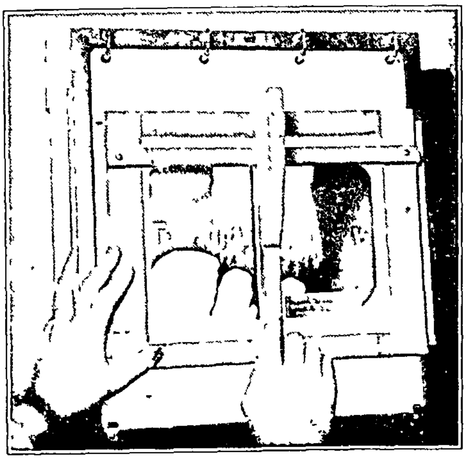

Fig. 5-C

Fig. 5-B

There were twenty-one private cases, with a total of twenty-seven abnormalities of the feet. Complete correction of all components by clinical or roentgenographic evidence was obtained in seventeen feet, or approximately 63 per cent. In two feet the deformities were corrected, except for slight adduction of the fore part of the foot, making a total of nineteen acceptably corrected feet, or 70 per cent. Deformities in twelve of the feet were completely corrected without lengthening of the tendo calcaneus. In both partially corrected feet, lengthening of the tendo calcaneus was required. Of the private cases, correction was obtained in eleven feet with one or two wrenchings, three were corrected with three wrenchings, and the remainder required from five to ten. The average length of time between wrenchings was one month, but ran up to one year, owing to recurrences of the deformity.

In the Clinic cases in which correction was achieved, two or three wrenchings were required. One case was corrected with one wrenching, and one case required seven. The average length of time which the patients spent in casts before complete correction was obtained ranged from three months to two years in the private cases, and from four months to four years in the cases treated in the Clinic; two and one-half years was the average for the Clinic cases and one and one-half years for the cases privately treated.

The age at onset of treatment ranged from six weeks to four or five years in both the cases seen in the Clinic and privately. In the Clinic, twenty-five patients were under six months of age and eleven were over six months of age; nine private cases were under six months of age and twelve were over six months. Of the patients treated successfully by this method in the Clinic, nine were under six months of age and seven were older. Of the series seen privately, ten were under six months of age and seven were over.

It might be well to re-emphasize that an attempt to correct the equinus should not be made until the adduction and varus have been corrected. Lengthenings of the tendo calcaneus were carried out in some of the cases treated by manipulation, prior to obtaining correction of the other components. This was a definite factor in causing failure of correction in these cases. In evaluating the cases in this series, fairly rigid criteria have been maintained for complete correction of adduction of the fore part of the foot.

A special cassette holder fashioned out of wood, with two crossbars, is now used (Fig. 5-A). The posterior part of the heel and the entire medial side of the foot are held firmly against the horizontal and vertical bars, respectively (Fig. 5-B). All roentgenograms are thus standardized (Fig. 5-C).

Most of the well-corrected congenital club feet treated by wrenchings are pliable. Incompletely corrected feet are usually rigid. This is mentioned, since it has been reported and is generally believed that all feet treated by wrenchings are rigid. A private patient, in whom wrenching for severe club-foot was carried out twenty years ago by Dr. Steindler, was seen recently. Roentgenograms showed perfect correction, and no evidence of bone injury or degeneration. The feet were pliable and painless.

With the use of the wedged-cast method, Kite reports successful treatment in 90 per cent. of his cases. He maintains that forcible manipulation under anaesthesia irreversibly damages the articular cartilage, which results in partial or complete ankylosis. The authors agree with this statement only in so far as the cases incompletely corrected by manipulation are concerned. In the cases treated by manipulation under anaesthesia in which complete correction was obtained, the feet were found to be pliable. In reviewing the roentgenograms of 100 consecutive cases treated by manipulations, which include the cases in this series, in only three cases was there some evidence of bone injury. In one case there was aseptic necrosis of the first cuneiform; in one there was a separation of the lower tibial epiphysis; and in one some destruction of the talus was present.

It is perfectly evident that we are dealing with a condition which is amenable not only to treatment, but to cure, provided proper management on the part of both the physician and the parents is brought to bear.

COMMON CAUSES OF FAILURE

Kidner stated that there are three principal causes of failure:

1. Delay in inauguration of treatment.
2. Imperfect nerve supply to the muscles, as in spina bifida.
3. Failure to obtain and to maintain complete overcorrection of the deformity.

With regard to the first cause of failure, it is obvious that, with the use of the Deni Browne splint or the Kite casts, the earlier treatment is started, the better the prognosi However, with the manipulative treatment under anaesthesia, this factor does not appea to be so important. It is often the fault of the parents that a baby with club-foot is no brought for treatment, but more frequently the fault lies with the family physician.

The second reason is self-evident. The third reason needs some elaboration. Kite, i 1935, stated that "an incompletely corrected club-foot or a relapsed club-foot is mor disabling than an untreated club-foot. The untreated foot is more stable and is a mucl more serviceable foot than a partially corrected foot."

No matter what the treatment, the maintenance of correction is of utmost importance We have all seen too many cases in which complete correction, both clinically and b roentgenogram, is obtained, only to be lost in subsequent months because of failure t maintain the correction in some suitable manner.

It is likewise of importance that the period of time between the reapplication of th Denis Browne splints should not be longer than from five to seven days,—preferably five With the Kite method of treatment, wedges should be taken every three or four days an casts should be changed completely after every third wedging. One of the reasons wh Dr. Steindler obtained better results in his private cases was that he manipulated the fee every three weeks or every month until correction was obtained.

A fourth cause of failure may be allergic manifestations to adhesive strapping an plaster-of-Paris. In several cases, another form of treatment had to be used because o allergic reactions to these materials.

Maintenance of correction should be active until all the tarsal bones are completel ossified. The parents should be instructed in their part of the after-treatment, and shoul be deeply impressed with their responsibility of gentle manipulation of the corrected feet

Fig. 6-A

Fig. 6-B

Fig. 6-A: Roentgenograms of patient with metatarsus varus, before treatment.
Fig. 6-B: Roentgenograms taken after treatment by wrenchings.

Fig 7-B Very good result was obtained after treatment by wrenchings and retentive casts

Fig 7-C Shows recurrence of the deformity one year later

Fig 7-D Aug 28, 1942 A very good result was obtained with a bilateral Brockman's operation lengthening of the tendo calcaneus, and Kite casts

Fig 7-E Jan 10 1946 The patient did not return the next year for follow-up, now, at the age of seven years wedge osteotomies will be necessary

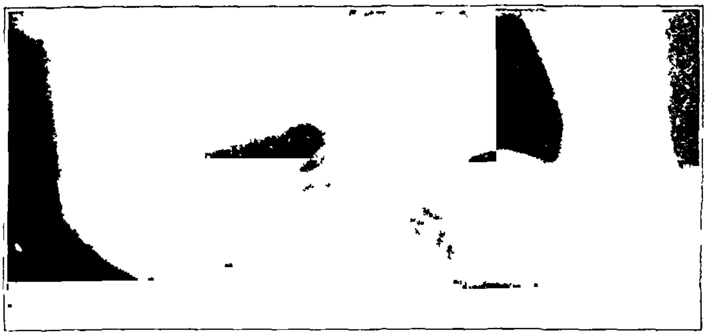

Fig 7-A
Roentgenograms of a patient at nine weeks of age

Fig 7-B

Fig 7-C

Fig 7-D

Fig 7-E

several times daily. They should also be impressed with the fact that they are to bring the child back immediately upon the recurrence of the slightest deformity.

The authors advocate the following regimen in the maintenance of correction: When

complete correction has been obtained, and only then, are the Denis Browne plates and bar attached to the soles of the shoes, with the right shoe on the left foot and the left shoe on the right foot. This arrangement is worn continuously until the child reaches walking age. The child is then fitted with a club-foot plate and full-length outer patches on the shoes.

The plates must be changed frequently to fit the foot. The club-foot plate is a flat piece of metal, the width and length of the foot, with three flanges or lips; one is on the lateral side of the foot, opposite the tarsometatarsal joint, and two are placed medially. The anterior lip opposes the head of the first metatarsal, and the posterior lip opposes the heel. This fits into the shoe and holds the foot in the position of correction. For a child who is active and walking, this is a valuable form of after-treatment for the waking hours, if properly fitted.

When the child first begins to walk, he is allowed to be up two hours a day for the first few months. The rest of his waking and sleeping time is spent in the shoes and the Denis Browne splint. The hours of freedom from the splint are gradually increased, depending upon the judgment of the physician; however, the splint is always used at night for at least two or three years after correction.

In regard to the metatarsus varus alone, without the other deformities, several of these cases have been treated with Denis Browne splints without success; on the other hand, a number of cases of metatarsus varus were treated with Kite casts with good results. The vast majority of the cases of metatarsus varus were treated by manipulation (Figs. 6-A and 6-B). Twenty-six feet in the private cases and ten feet in the series seen in the Clinic were thus treated. Of the private cases, twenty-three had excellent results, two improved, and failure occurred in one case. Of the cases seen in the Clinic, complete correction was obtained in eight and partial correction in two.

Certain disadvantages are associated with each of the three methods:

With the Denis Browne splint, constant attention is required. The adhesive strapping must be changed every five to seven days, which necessitates frequent visits or long periods of hospitalization, entailing considerable expense.

Use of the Kite casts requires frequent wedges and changes of cast, which also entail frequent treatments or a prolonged stay in the hospital. In addition, the personal equation of the doctor treating the patient is of utmost concern, because of the necessity for meticulous care in the taking of wedges and the application of casts.

Manipulation under anaesthesia has the following disadvantages:

1. An anaesthetic is necessary, with all the risks involved.
2. The period of immobilization in plaster is longer.
3. The personal equation is of greater concern here than with the wedged-cast method.
4. There is danger of permanent bone or joint changes. This is, of course, inversely proportional to the experience of the orthopaedic surgeon instituting the treatment.
5. Frequent upper respiratory and contagious diseases prevent the giving of anaesthetics, which cause undue delay and interruption of treatment.

The maintenance of correction is of the utmost importance, and cannot be emphasized too strongly. In this regard, one case is illustrated in which correction was not maintained because of failure to retain the foot in the corrected position for a prolonged period (Figs. 7-A, 7-B, 7-C, 7-D, and 7-E).

CONCLUSIONS

1. Treatment of club-foot should be instituted as early as possible.
2. The Denis Browne splint, alone or complemented in some cases by another form of conservative therapy, gives the best results, especially in patients under one year of age.
3. In cases in which the Denis Browne splint failed to obtain complete correction, or

in those patients who are between one and four years of age at the beginning of treatment, wedged casts should be used.

4. In some cases of metatarsus varus, correction can be accomplished with wedged casts.

5. Under certain conditions in private practice, manipulative methods may not be the method of choice, but rather of necessity. In expert hands, good results can be obtained by the manipulative method.

6. The manipulative method can be used in patients in the older age groups.

7. Metatarsus varus can either be completely corrected or markedly improved by manipulative methods.

8. Correction must be maintained for a considerable period of time, preferably as described.

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A SPLINT FOR TREATMENT OF RECURRENT CLUB-FOOT *

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About a year ago a new splint was designed at our clinic for the final treatment of recurrent club-foot. It has been named the "spring splint", and has proved to be of outstanding value and satisfaction. It is applicable only to the child of active-walking age.

The recurrent club foot usually shows varying degrees of the following deformities:

(1) Equinus—the foot cannot be dorsiflexed to a right angle;

(2) Varus—this varies considerably in different feet and may even remain as a subtalar varus permanently, in spite of treatment;

(3) Adduction of the fore part of the foot, which is not of much consequence, and tends to correct itself when contraction of plantar fascia has been obviated.

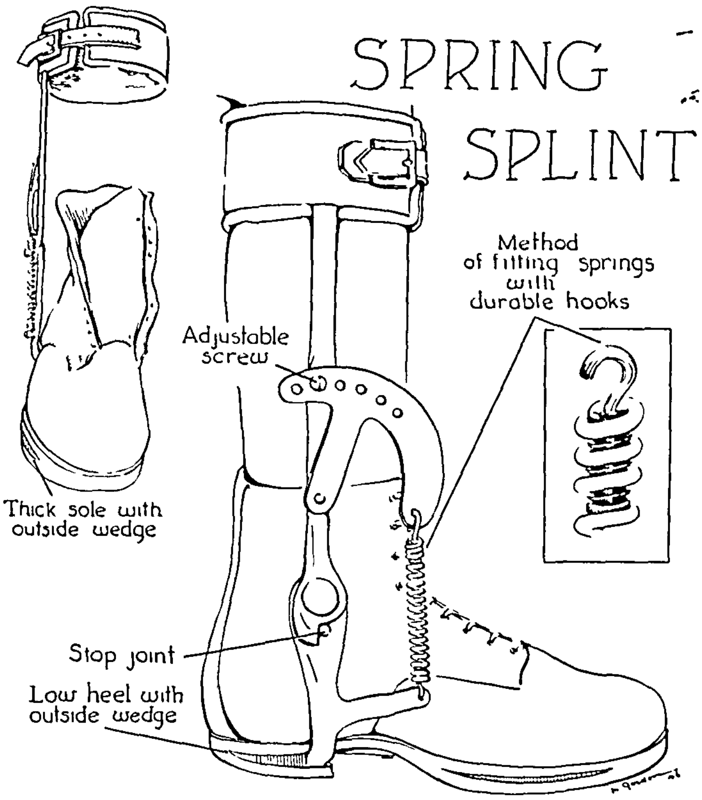

FIG. 1

It has been our custom to have the patient admitted to the Hospital and given a general anaesthetic. If the degree of equinus is not very great, only a plantar fasciotomy and manipulation may be done, followed by application of a plaster cast. It may be necessary to do one or more manipulations at intervals of three or four weeks. When the fore part of the foot can be readily dorsiflexed to a right angle or better, the patient is ready for the spring splint.

When a club foot can be dorsiflexed to a right angle or more, the recurrent tendency is greatly lessened; moreover, the adduction and varus deformities (if still present) become lessened spontaneously. On the other hand, if the degree of equinus is great, it may be necessary to do a lengthening of the tendo calcaneus and a posterior capsulotomy. This procedure may be followed by one or more manipulations and possibly by a plantar fasciotomy as well.

Prior to the use of this splint, the parents were then instructed in daily manipulation of the feet, and the patient was provided with boots. Repeated recurrence was frequent, until finally an arthrodesis was decided upon.

Since the advent of the spring splint, the results in recurrent club-foot have improved tremendously. The splint is applied when correction to a right angle or better has been obtained. At the start, it is kept on night and day. No further manipulations by the parents, or exercises, are necessary. However, the patient is encouraged to take up roller-skating, ice-skating, and skiing, because these sports all require repeated and active degrees of dorsiflexion.

Since the spring splint has been used, our operative measures and the number of manipulations have been greatly modified. In other words, many patients, upon whom a tendon lengthening would formerly have seemed necessary, now require only a plantar fasciotomy. The splint does the rest of the work.

* The Denis Browne method of treating club-foot[1] still remains a highly efficient one with an excusable number of recurrences.

The design of the splint is simply a lateral single bar below the knee brace, with a stop joint. It is fitted on our standard club-foot boot, which is a good boot with a low heel and a thick sole and an outside wedge of three-sixteenths of an inch on heel and sole. The two segments of the splint are then united by an adjustable hinge-like apparatus with an intervening spring.

The springs are manufactured in three sizes to suit the varying sizes of both child and splint. A great deal of difficulty was encountered at first, because the springs were breaking at the point of contact with the splint, due to inevitable friction. This has been overcome by removing the hook end, which was just a continuation of the spring coil, and replacing it with a much stronger hook. The new hook is embedded in a metal plug which is threaded inside the spring.

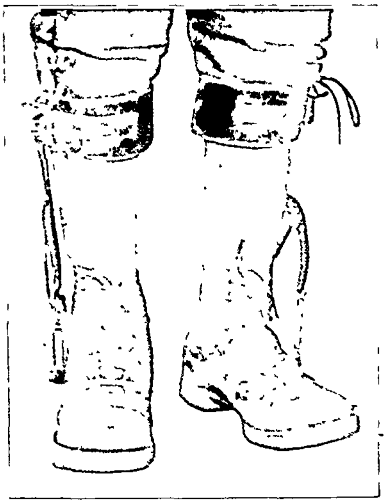

Fig. 2-A

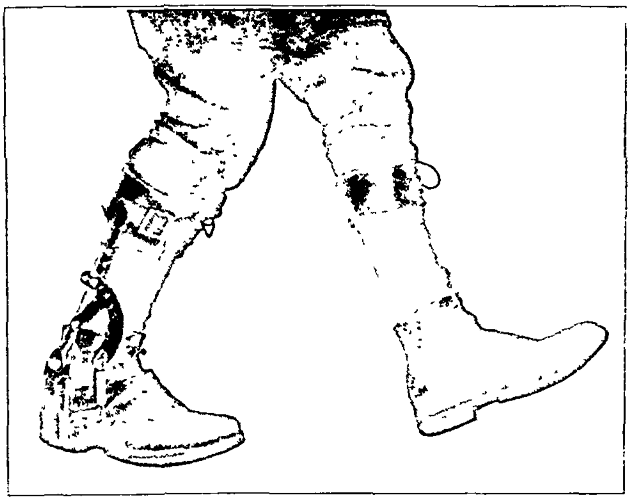

Fig. 2-B

Demonstration of boots for club-foot.

The specifications of the springs, which are made of music wire, are as follows:

	Small	*Medium*	*Large*
Diameter of wire	0.036 inch	0.048 inch	0.064 inch
Outside diameter of spring	0.25 inch	0.344 inch	0.375 inch
Number of coils	24	24	26
Tension at one-inch pull	9 lbs.	14 lbs.	22 lbs.

Six of the medium-sized springs are used to every one of the small or large springs.

Too much tension must be avoided, particularly at first, because of danger of a pressure sore either on the heel posteriorly or over the anterior aspect of the ankle. Additional methods of preventing this complication are to pad the tongue of the boot and to be sure that it is firmly laced, so that the heel is well down in place and unable to shift its position. The adjustable screw (Fig. 1) makes doubly sure that the tension is correct.

This splint has also been used satisfactorily on children beginning to walk after correction has been obtained, but in whom inevitable recurrence, due to lack of parental care, is feared. However, it is not used in the routine treatment of club feet which have responded satisfactorily and are being well supervised.

The reverse model of this splint has proved helpful in the treatment of a few cases of calcaneovalgus club feet.

Note: The writer wishes to express his sincere thanks to the Orthopaedic Shop at the Hospital for Sick Children for its continuous and courteous help and expert workmanship.

1. Thomson, S. A.: Treatment of Congenital Talipes Equinovarus with a Modification of the Denis Browne Method and Splint. J. Bone and Joint Surg., 24: 291–298, Apr. 1942.

THE TREATMENT OF PARALYTIC CALCANEUS

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PHYSIOPATHOLOGICAL CONSIDERATIONS

The calcaneus foot (talipes calcaneus) is not an infrequent sequel of anterior poliomyelitis. It follows paralysis of the triceps surae. The following pathological phenomena appear as a consequence of paralysis of the sural triceps:

1. *Loss of Flexion of the Foot*

With loss of function of the calf group the gait is steady, but greatly handicapped. It is impossible not only to plantar-flex the foot, but also to propel the body forward. Because of this, it is necessary in walking that the center of gravity of the body be kept posterior to the ankle in order to avoid automatic extension (dorsiflexion) of this joint. Consequently, it is necessary to shorten the forward swing of the other limb.

2. *Progressive Elongation of the Triceps Surae*

As a result of stretching of the paralytic calf group, there is an increase in the range of passive motion of the ankle in extension. This modifies the normal physiological stimulus, which influences the bony development of the talus. In consequence, the shape of the talus becomes altered, and the head and distal portion of the neck assume a more elevated position in relation to the rest of the bone.

3. *Loss of Balance between the Plantar Muscles and the Triceps Surae*

In this condition the calcaneus may be influenced by the plantar muscles only, thus altering the mechanical stimuli which normally affect the growth of this bone; the part exposed to the plantar-traction stimulus keeps on growing, and the posterior part becomes atrophied. The calcaneus becomes more and more deformed, until the heel attains its characteristic form,—that of the butt of a pistol. Likewise the lever arm of the calcaneus is shortened. As the weight-bearing surface of the calcaneus is reduced, balance becomes difficult.

4. *Increase of the Talocalcaneal Angle*

In the author's opinion, all anatomical and mechanical changes are represented by the increase of the talocalcaneal angle (*AOC*, Fig. 1). The importance of this angle was discovered by the author during a study of Professor Putti's cases of paralytic calcaneus at the *Istituto Ortopedico Rizzoli*, Bologna. Normally, the axis of the talus, that of the first metatarsal, and that of the calcaneus meet at a point which we call the "axial center" (Fig. 1). The talocalcaneal angle has a normal value of about 50 to 55 degrees. The increase of this angle represents calcaneus deformity, and consequently the amount of this increase indicates the anatomical and static changes.

5. *Trophic Changes in Joint Capsules and Ligaments*

The ligaments and capsules, especially of the talotibial and subtalar joints, are affected by poliomyelitis. Consequently, there is not only an increase in the passive motion of these joints (flexion-extension in the ankle, pronation-supination in the subtalus), but, what is far more important, abnormal motion occurs.

In the ankle, lateral movement is usually in the direction of pronation. As a result, growth of the external part of the talar body is less than normal. A vicious cycle of deformity and abnormal mobility is established.

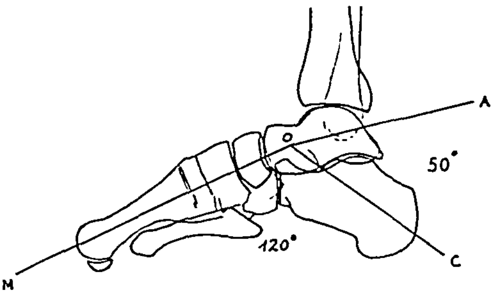


Fig. 1

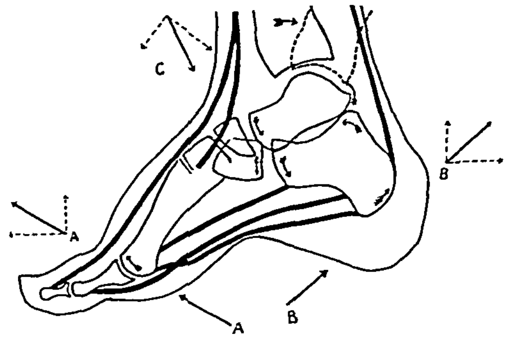


Fig. 2

Fig. 1: Axes and angles in the normal foot.
O: Axial center. *A*: Axis of astragalus (talus).
M: Axis of first metatarsal. *C*: Axis of calcaneus.

The axes are determined as follows: A roentgenogram is made, with the lateral surface of the foot resting upon the cassette. Lines are then drawn, (1) bisecting the first metatarsal, (2) from the tip of the posterior tubercle of the calcaneus through the deepest point on the calcaneal surface of the sinus tarsi, and (3) from the posterior border of the upper articular surface of the talus through the center of the head of that bone.

Fig. 2: *A*, *B*, and *C* show the three forces which must operate to correct a calcaneocavus foot, after it has been placed in plantar flexion.

In the subtalar joint, in addition to an increase of lateral movement, it is possible to find pathological motion of flexion-extension. This movement is slight; but, by means of hand pressure (Figs. 3-A, 3-B, and 3-C), a modification of the talocalcaneal angle can be demonstrated. Consequently, it is possible to speak of a calcaneal rotation, produced by the tension of the plantar fascia and muscles, which is added to the anatomical changes in this bone.

6. *Other Physiopathological Relations in the Foot*

In addition to the changes mentioned, talipes cavus appears frequently in the calcaneus foot. The action of the plantar muscles, as well as that of the extensors of the great toe and the peroneus longus, can intervene in its pathogenesis. The geometrical representation of the cavus deformity is the increase of the angle formed by the axis of the calcaneus with that of the first metatarsus, and the division of the axial center (Figs. 4-A, 4-B, 5-A, and 5-B). Likewise, when the tibiales are paralyzed, calcaneus flat-foot may follow. In this case the talocalcaneal and the metatarsocalcaneal angles are increased.

The paralytic syndrome in the foot has more or less functional importance, according

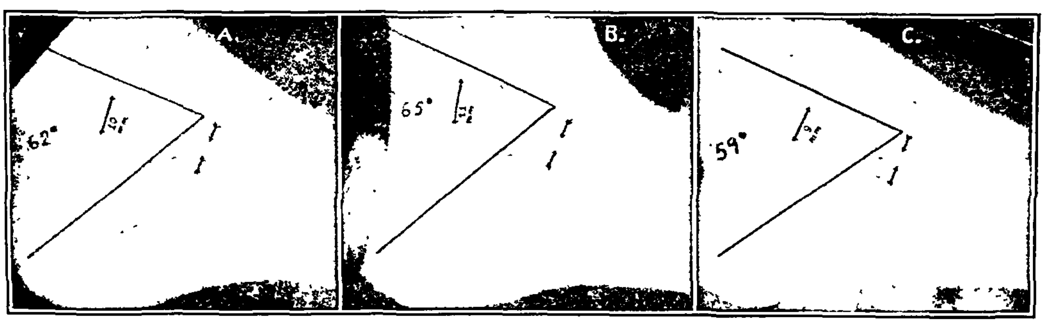


Fig. 3-A Fig. 3-B Fig. 3-C

Roentgenograms of a calcaneus foot (slight deformity).

Fig. 3-A: Normal position of the foot.

Fig. 3-B: Increased deformity, due to pressure over the back of the calcaneus and to stretching of the plantar muscles.

Fig. 3-C: Deformity corrected by means of pressure over the lower aspect of the calcaneus. The talocalcaneal angle can be modified, thus proving a pathological mobility at the level of the subtalar joint. In order to show clearly the space between the talus and the calcaneus, the talar axis was traced through the most prominent part of the posterior surface of the talus, which is seen in the roentgenogram. For this reason the size of the angle is greater than normal, because the talar axis was not traced in the correct position (See Fig. 1).

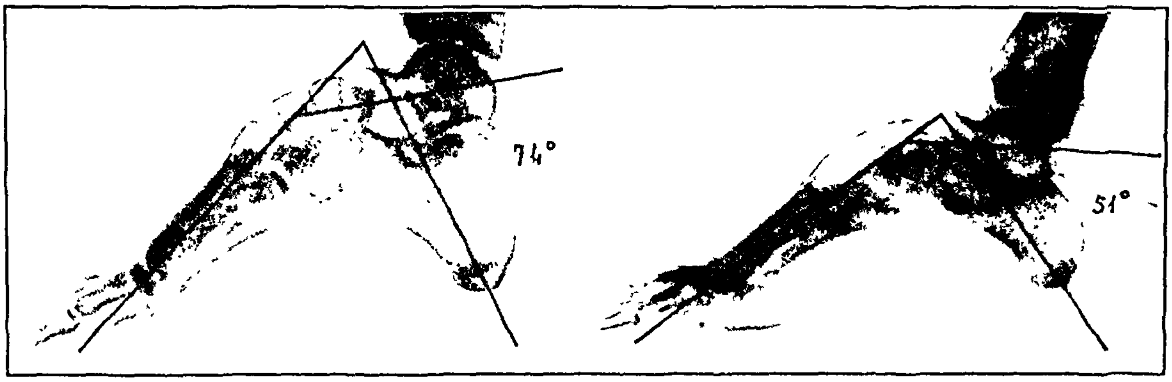
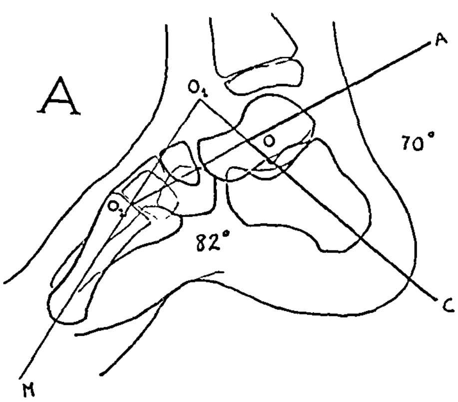


FIG. 4-A FIG. 4-B

Calcaneocavus foot before and after cuneiform subtalar arthrodesis. Note the displacement of the axial center, which remains in spite of the fact that the back of the foot is maintained in physiological position (talocalcaneal angle of 51 degrees). There exists, then, a cavus of the fore part of the foot, which must be corrected.



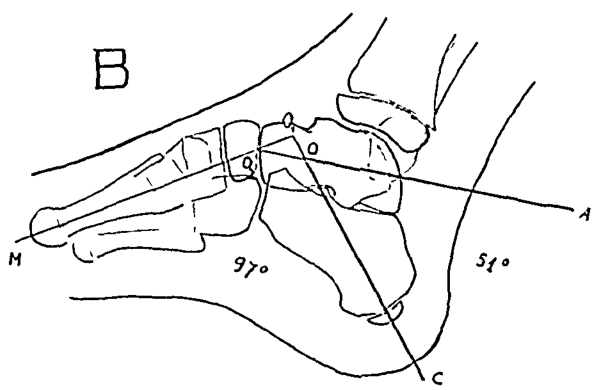


FIG. 5-A FIG. 5-B

Tracings of roentgenograms of a calcaneocavus foot, before and after subtalar arthrodesis and anterior arthrorisis, according to Putti's second method (one year after surgical intervention). The calcaneus deformity has been corrected. The morphology of the calcaneus and talus approximates normal. A slight cavus in the fore part of the foot still persists.

to the functional condition of the limb. If the quadriceps is paralyzed, the gait is greatly handicapped; and, if the glutei are also paralyzed, walking becomes impossible. Likewise, if the knee is contracted in flexion, weight-bearing becomes impossible, because of the displacement of the center of gravity.

All these considerations must be taken into account before treatment is undertaken.

TREATMENT

During Period of Recovery

After the acute stage, postural treatment is necessary. The foot is maintained in flexion to counteract the pull of the plantar muscles. If deformity is just beginning and the triceps retains any force, this procedure may be sufficient to correct the deformity (Fig. 2).

After the Deformity Has Become Established

The function of the triceps can, theoretically, be provided by transplantations, but it is necessary to consider, as Fick does, that the triceps has a force of 16.37 kilograms. The sum of the force of the other muscles of the leg is 6.58 kilograms. This means that transplantations can help in improving function, but they are not sufficient to avoid the pathological consequences of triceps paralysis.

In theory, stretching of the triceps can be treated by tenodesis or by shortening of the tendo calcaneus; but elongation appears again, if not prevented by other means.

Hyperextension of the foot can be prevented by arthrodesis or by arthrorisis (arthroereisis) of the ankle. After the first operation, the tibiotalar joint is rigid and the gait is

FIG. 6-A
Normal side.

FIG. 6-B
Paralytic side.

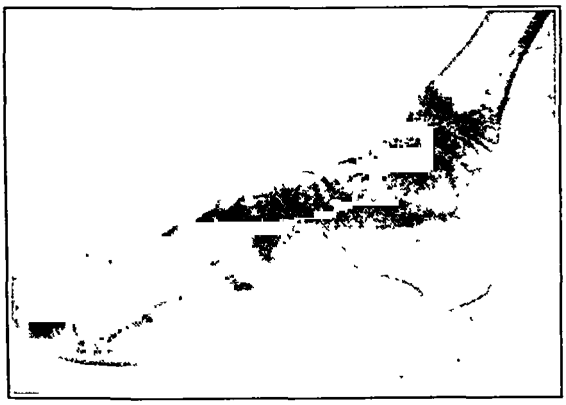


FIG. 6-C

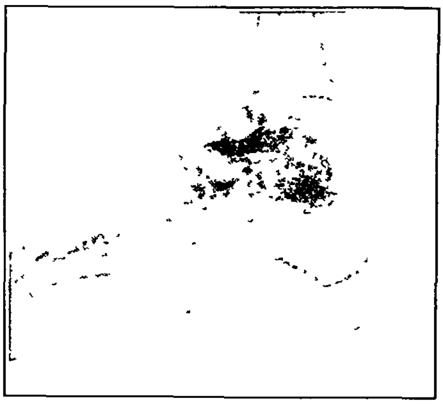


FIG. 6-D

Same patient after the operation (subtalar arthodesis, anterior arthrorisis, and transplantation of both the peroneal muscles to the calcaneus).

Fig. 6-C: Plantar flexion. Fig. 6-D: Dorsiflexion that shows the action of the arthrorisis.

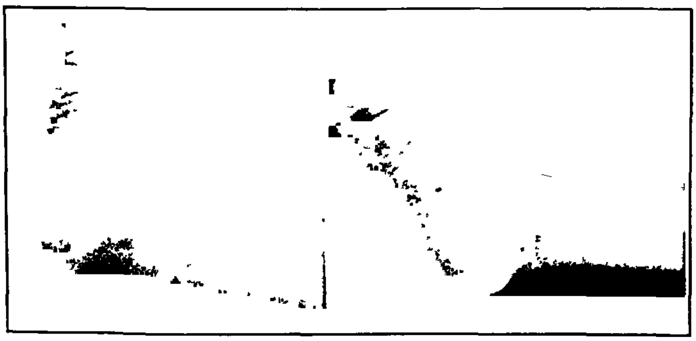


FIG. 6-E FIG. 6-F

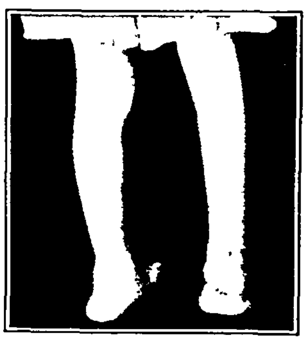


FIG 6-G

Fig. 6-E: Active dorsiflexion Fig. 6-F: Active plantar flexion.
Fig. 6-G: The weight-bearing on the fore part of the foot is satisfactory.

unsatisfactory. Moreover, the calcaneus can continue to rotate, and it is necessary also to perform a subtalar arthrodesis. This may be indicated when the ankle possesses great instability and when the fore part of the foot is not deviated, in order that the mediotarsal joints may afford sufficient compensation. The operation of choice is the anterior bone-block. By this operation, passive hyperextension of the foot is prevented and the normal growth of the talus is permitted (Figs. 5-A, 5-B, 6-A, and 6-B).

PUTTI'S TECHNIQUE[2,3]

An anterior incision is made from the lower tibial epiphysis to the level of the mediotarsal joint, with the foot in extreme plantar flexion. Care must be taken to avoid the musculocutaneous nerve. The incision is then carried inward, between the extensor digitorum communis and the extensor hallucis longus. The anterior tibial artery and nerve are retracted medially with the long extensor of the great toe, thus exposing the capsule of the ankle joint. Formerly Putti opened the joint; later this exposure was abandoned in an effort to avoid traumatic joint changes. Immediately distal to the capsular attachment to the talus, a curved osteotome is gradually introduced into the bone in the horizontal plane. As the instrument penetrates the cancellous bone, an upward prying force is gently imparted to it. It is generally sufficient to osteotomize the bone to a depth of 1.5 centimeters.

The lamina thus created is pried up cautiously as far as possible. With reasonable care, fracture can be avoided. Of the forty-odd cases in the author's experience, fracture has been avoided in all. This is attributed to two factors: first, the gentle upward prying with each successive penetration; and, second, the thickness of the osseous lamina, which should not exceed three millimeters.

When a block, sufficient to limit dorsiflexion of the foot at the predetermined angle, has been obtained in this way, a cancellous bone graft is impacted into the osteotomy slot, while the blade of the osteotome is still in place. The blade is then withdrawn. The graft used has been prepared previously, at the time of the subtalar arthrodesis.

Tendon transplantations are performed at this point, if indicated.

In the author's modification of the operation, when the talus is in the valgus position, correction is obtained through greater lateral elevation of the lamina. The plaster cast is worn for three months, maintaining the foot in equinus, or in equinovarus when the modification has been performed. Exercises and progressive weight-bearing are then permitted, the patients walking with crutches.

In time, the block attained at operation decreases; but, under the stimulus of weight-bearing, the bone becomes hypertrophied, and sufficient check can be expected if weight-bearing is controlled. Excessive weight-bearing before organization of the elevated bone tends to lower the block and results in too much dorsiflexion. On the other hand, a slight amount of weight-bearing—such as for five or ten minutes daily—actually stimulates the bone and hastens the remodeling of bone structure until this becomes adequate. This may require from two to four months of careful supervision, during which time weight-bearing is progressively increased.

The typical deformity of the heel is easily corrected, and may be prevented by subtalar arthrodesis, which also reestablishes the normal value of the talocalcaneal angle. Usually the arthrodesis should be wedge-shaped; the quantity of the wedge to be extirpated is indicated roentgenographically by the opening value of the talocalcaneal angle. Moreover, subtalar arthrodesis prohibits pathological motion in this joint, and makes the support stable and the gait more secure. The lateral motion in the talocalcaneal joint is treated by the modified arthrorisis of Putti. In this modification, the lateral portion of the upper articular surface of the talus is raised, thus correcting the valgus (Figs. 6-C to 6-G).

Mention should be made of the associated paralysis of the quadriceps femoris. If passive hyperextension of the hip and the knee had been present prior to operation, this

FIG. 7-A FIG. 7-B

Roentgenogram and photograph of a calcaneovalgus foot three years after subtalar and mediotarsal arthrodesis and anterior arthrorisis.

condition was automatically corrected mechanically by the arthrorisis, provided it blocked the ankle at 100 degrees. This was demonstrated by Putti.

END RESULTS

The series presented herewith has been taken from a group of fifty cases of paralytic calcaneus foot observed in the *Hospital Central de la Cruz Roja de Madrid* and in the *Instituto Nacional de Reeducación de Inválidos*, Madrid. Twenty-five patients were operated upon; twenty-one were suitable for arthrorisis, which in thirteen was anterior, and in eight anterolateral. In order to correct such conditions as valgus, varus, or cavus deformities, or claw-foot, calcaneocuboid and talonavicular arthrodeses have in some cases been necessary, as well as tendon transplantations. Seventeen of the twenty-one patients have been considered satisfactory for end-result study from the standpoint of time and proper follow-up.

In all of the seventeen patients, subtalar arthrodeses were performed; in seven, transplantations of the peronei were possible. Peroneal transplantations will probably be performed later in a number of these cases, when the children are sufficiently mature to cooperate in reeducation of the transplanted muscles. Their ages varied from four to fifteen years, with the majority between five and thirteen years of age.

Examination by the author of the series of cases operated upon by Putti disclosed uniformly good results when the extra-articular technique had been employed properly, and the after-care could be carried out. These patients had been operated upon many years before. In them no osteo-arthritic changes were found, and the full mechanical effect of the bone-block proved to be lasting.

The end results have been considered from the standpoints of form and function. Results have been considered to be "good", morphologically, when the foot was of approximately normal appearance clinically, and by roentgenogram the talocalcaneal angle was shown to be between 50 and 55 degrees. The result is recorded as "poor" if there was valgus, varus, or a flat foot.

Functional results have been estimated with consideration of the muscle power present before operation. A patient, lacking muscles suitable for transplantation, was considered to have a good end result when dorsiflexion at the ankle was limited at 90 degrees. The result was also considered to be "good" if a patient who had "fair" transplanted muscles, subtalar arthrodesis, and anterior arthrorisis could walk "over the toes" (Fig. 6-G).

The result is considered "poor" if the block corrects dorsiflexion of the ankle at an angle, formed by the long axis of the leg and the foot, which is less than 90 degrees. If

paralysis of the quadriceps exists and the bone block does not arrest dorsiflexion at the ankle at from 90 to 100 degrees, the arthrorisis will not result in hyperextension of the knee in walking, and the result is considered poor.

The author's series is too recent to justify final conclusions in these respects. Six patients were examined four years or more after arthrorisis. Of these, four, or 67 per cent., are considered to have functionally good results; in two, or 33 per cent., the results are poor. Eleven patients were examined from one to three years after arthrorisis; provisionally, the results in nine, or 82 per cent., were considered good, and in two, or 18 per cent., poor. The poor results in both series of cases are due to insufficient bone-block, and a second operation has therefore been performed on these patients. The second operation was not technically difficult.

No arthritic changes or abnormal growth of the lower tibial epiphysis has been observed as yet in this series. Morphologically, all patients are considered to have attained good results.

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TREATMENT OF CONGENITAL FLAT-FOOT *

BY JAMES E. M. THOMSON, M.D., LINCOLN, NEBRASKA

The medical profession has been criticized for lack of recognition and adequate correction of many disabilities which showed up in Army inductees who appeared before Selective Service examiners. Among the common foot disabilities was symptomatic flat-foot, in various degrees of severity. The questions which are frequently raised with respect to the foot complaints of the adolescent and young adult are as follows:

1. Why should healthy-looking, well-developed young men be afflicted with poor feet? They may or may not have a long history of foot trouble. Sometimes their symptoms are attributed to military training.
2. Would it be reasonable to suggest that they had from babyhood exercised and developed their musculoskeletal system normally, with perhaps the exception of their feet?
3. Might it not be possible to develop criteria by which one might early (before walking is begun) recognize those feet which might be potentially weak or show pronation? To investigate such a problem, the pediatrician must look for and recognize physical anomalies and evidences of weakness in the baby's foot and realize that, just because a child does not have club-foot, he does not necessarily have normal feet.

Several frequently observed characteristics of the infant's foot, which seem to bear a definite relation to future foot weakness or to act as potential forerunners of flat feet, will be discussed.

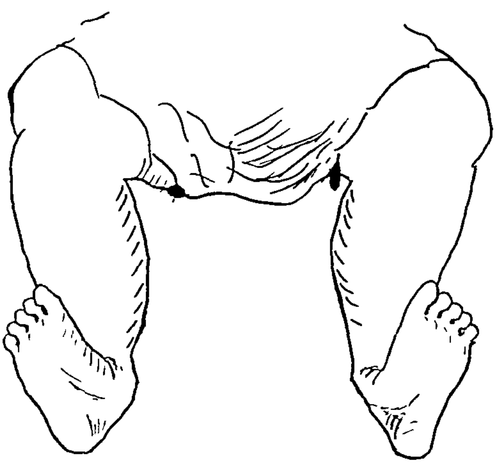

Fig 1

Fig. 2

Fig. 1: Congenital weakness of the foot is readily recognized by hyperflexibility, particularly the ease of ability to place the dorsum of the foot in the calcaneovalgus position against the leg.
Fig. 2: Pronounced pronation and eversion are shown as the child crawls.

Some infants have abnormal mobility of the foot in all directions, and a particular fondness for an everted calcaneovalgus position. These babies have the tendency to throw their feet, while kicking, from a varus to an extreme calcaneovalgus position. Usually the dorsum of the foot can be brought manually, without force, against the anterolateral part of the leg (Fig. 1). These babies are often belly sleepers, and in this position they habitually evert their feet. When they learn to sit, they assume a position of abduction, with the

* Read by J. Warren White, M.D., at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1946.

knees flexed and the feet everted. The eversion of the feet is exaggerated during crawlin (Fig. 2). When the infant begins to walk, the legs rotate outward, and pronation an eversion of the feet are thereby exaggerated (Fig. 5-A).

On the basis of five years of observation, the author believes that the characteristic described above constitute a distinct objective entity, which signifies congenital weaknes of foot structure. These findings are far more common than is realized. The deformit accompanying the manifestations may to a certain extent be overcome by growth, development, and activity of the child, or by late recognition and adequate therapy. We believe however, that many of these children have "foot complaints" at some time before or afte adolescence.

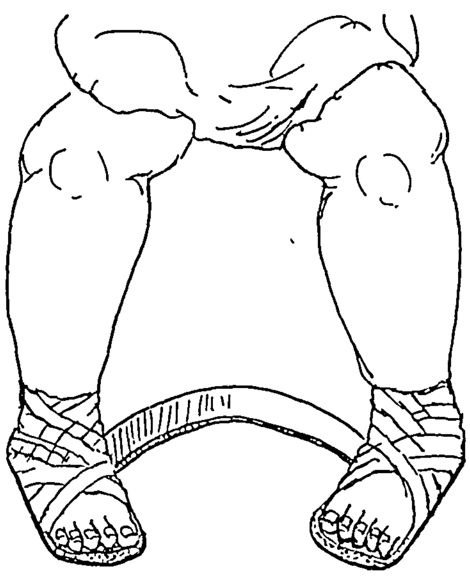

FIG. 3

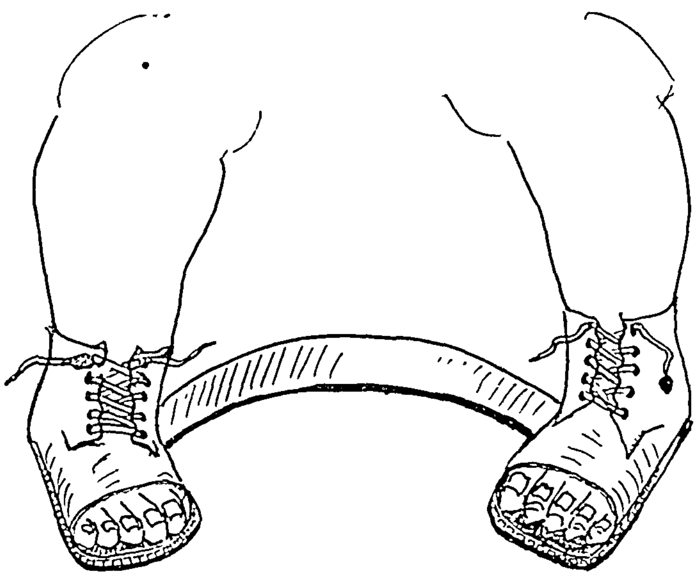

FIG. 4

Fig. 3: Sketch of the reverse Denis Browne splint, with the bend of the bar toward the crotch.

Fig. 4: Shoes with toes cut out are used for older children. When the child begins to walk, the splint is used at night.

TREATMENT

For some years the author has used the Denis Browne splint in certain cases of club-foot, with satisfactory results. In one instance of a unilateral club foot, the opposite foot was abnormally mobile and had a tendency to calcaneovalgus posture. In this case an attempt was made to turn the varus foot out and the valgus foot in by means of the same splint. An S-shaped cross iron was prepared so that the club foot was on the down side and turned out and the valgus foot was on the up side and turned in. As the child exercised the legs and feet in order to correct the club foot, the valgus foot became more varus and stable. It is difficult to tell now, after three years, which is the varus and which the valgus foot.

This experience led to the use of a Denis Browne splint in reverse for the treatment of congenital talipes calcaneovalgus. Instead of having the cross bar bend away from the crotch as it does in the correction of club-foot, it is bent toward the crotch; and instead of the foot plates being turned out, they are turned in. Therefore, this treatment is referred to as the reverse Denis Browne splint (Fig. 3).

TECHNIQUE

1. As in the treatment of club-foot, the earlier a foot weakness is recognized, the shorter is the period of treatment and the more gratifying the result. Therefore, the optimum time to begin treatment is when the infant is from one to three months of age.

2. The foot plates are strapped on after the foot has been painted with compound tincture of benzoin; strapping is carried out exactly the same as for club-foot. Because of the usual hyperflexibility of the foot, it can be inverted in extreme correction on the bar, which is bent toward the crotch. A masking tape (made of crepe paper), three-quarters of an inch wide, when reinforced by one-inch cotton bandage, is tolerated longer by the skin than is adhesive tape. Re-strappings are made every one to three or four weeks. The feet are watched carefully between strappings.

3. As soon as the foot has developed in size suffi-

Fig. 5-A

Fig. 5-B

Fig. 5-A: A child, ten months old, has pronounced foot weakness.

Fig. 5-B: Same child, at age of four years, has strong feet. Splints were worn for four months during the day, and then used only as night splints. Child wears mildly corrective shoe.

ciently to take a hard-soled shoe (size one or two), the shoes are riveted to the plates. The toes of the shoes are always cut out to allow penetration of air and freedom of motion (Fig. 4). A carefully trimmed, well-fitted, soft sponge-rubber pad is pasted in the shoe to follow the normal longitudinal contour of the arch. Its purpose is much the same as that of overcorrection of clubbing by the wedging of casts. The aim is to promote the normal contour of the foot by a mild lift in this region during muscular activity. The child is seen every month or two during the next six or seven months; and, as the foot increases in size, the shoes are changed on the plates and the cross bar is lengthened. Splints are removed daily for bathing and massage and for an hour or so of freedom.

4. At the age of ten or twelve months the child is fitted with walking shoes. Again, longitudinal soft pads are fitted and are glued into the shoes. Sometimes a lift inside the heel is advisable. The child is encouraged to take his first steps. When the child has his nap and at bedtime, the reverse Denis Browne splint is put on and its use is continued until the child's foot shows a normal response to all exercises and activities. The length of time, of course, varies for every patient. When the treatment is started early, the splints are often dispensed with between the ages of one year and fourteen months. When treatment is started late, night splints have been required even up to two

Fig 6

Denis Browne splint treatment was recommended when this child was six months old, but it was refused. At four years, the patient complains of his feet and shows marked weakness.

years of age. Heel lifts, Thomas heels, and sometimes soft pads inside the shoe must be continued indefinitely. Exercises after three years of age are most valuable when there is proper parental cooperation.

COMMENT

Faulty posture, instability, and abnormal mobility are all aggravated by habit. When these characteristics are combined with congenital weakness of the infant foot, the condition must be corrected by the following means: Proper muscle activity in the right, or overcorrected, posture must be developed and new habits of the intrinsic foot muscles as well as of the extrinsic leg muscles must be created. Furthermore, by the apparatus described, which encourages proper muscle activity in a corrected position, the weakness can be overcome and the defects can be corrected.

Over fifty patients from one to four years of age have been observed, and the results have been uniformly gratifying (Figs. 5-A and 5-B). In a smaller group of control cases, the arduous ordeal of the splint treatment was refused. Most of these children, although still quite young, have pronated valgus feet and several are already symptomatic (Fig. 6). A few, however, have developed fairly normal feet. The question, of course, remains as to what will happen to these patients later in life.

Since the congenital club foot is usually a foot with limited possibilities, many of the congenital flat feet which have been treated, although they look normal, may require continuous supportive measures and exercise in order to maintain normal function.

DISCUSSION

Dr. Lenox D. Baker, Durham, North Carolina: Dr. Thomson described the use of the Denis Browne splint in the treatment of calcaneovalgus deformities of the foot in one of his Orthopaedic Correspondence-Club letters. During the past year we have used the splint, as suggested by Dr. Thomson, and have been most pleased with the early results. The splint has its limitations; it is of little or no use in the foot with a long talus, and it is of little permanent benefit in a foot with an accessory navicular. As Dr. Thomson has pointed out, its greatest use is in the uncomplicated calcaneovalgus deformity. The splint brings about an early correction of the valgus deformity; and in many of our cases we have seen a rapid return of active inversion, and have seen the posterior tibial and the abductor of the great toe brought back into active participation in the motions of the foot.

Dr. J. Warren White, Greenville, South Carolina (closing the discussion in the absence of Dr. Thomson): I find no points of disagreement with Dr. Thomson's data, and only wish to mention a simple expedient, which in my hands has been most useful as a supplementary procedure.

Some parents, as Dr. Thomson has inferred, refuse to permit the use of a splint of this nature before the child begins to walk, particularly because the abnormality—one cannot call it a deformity—seems so trivial.

The reverse Denis Browne splint is much simpler than the plaster casts which we have all been using on the severe cases. Since Dr. Thomson described the procedure in his Correspondence-Club Letter, I have been using it when necessary, concluding the treatment, however, with a yet simpler procedure, which has been used solely in the mild cases.

In those instances, therefore, where an even more conservative method may be desired, I have been sticking together the soles of these infants' hypermobile flaccid feet with a commercial adherent or compound tincture of benzoin, and holding them with a two-inch elastic bandage. In many instances we tend to neglect treatment in children with everted feet, and it is particularly in these cases that the sole-to-sole position for maintaining equinovarus is indicated.

We hold the soles together until the child maintains the inverted position most of the time, which is usually in three or four months. There has been no objection to the method on the part of the parents. They are afraid of a splint, but will tolerate putting the feet together.

We all are indebted to Dr. Thomson for calling to our attention the need of doing something about these functionally disordered feet, and for suggesting a practical method for the correction of the severe cases.

INTERNAL FIXATION OF TROCHANTERIC FRACTURES OF THE FEMUR

Report of 103 Consecutive Cases

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During the past few years, considerable interest has been shown in the operative treatment of trochanteric fractures of the femur. In many clinics, this treatment has become almost as standardized as the operative fixation of fractures of the neck of the femur.

The purpose of this paper is to present a satisfactory operative technique, and to point out the advantages of operative treatment,—lowered mortality, shortened convalescence, and improved anatomical and functional end results.

The authors' conclusions are drawn from experience gained in the operative treatment of 103 consecutive cases on the Orthopaedic Service of the St. Louis City Hospital. Excluded from this report are three patients who refused surgery and four who, for reasons other than the fractures, were moribund on admission.

The average age of the patients in this series was 70.6 years. The youngest patient was fifty-two years old; the oldest was eighty-nine.

TABLE I
Types of Anaesthetics Used

	Number of Cases	Number of Deaths	Mortality (*Per cent.*)
Spinal anaesthesia	29	4	13.8
Ether (drop)	10	2	20.0
Pentothal sodium and nitrous oxide	34	3	8.8
Local anaesthesia	30	13	43.4
Totals	103	22	21.4

ANAESTHESIA

Table I illustrates the types of anaesthetics and their relation to mortality. Noteworthy is the mortality rate of 43.4 per cent. for local anaesthesia, as compared with 8.8 per cent. for pentothal sodium and nitrous oxide. These figures do not represent selection of cases. In the early part of the series, local anaesthesia was used almost entirely in the belief that it was to be preferred in this age group. The results did not justify this opinion. Insufficient relaxation, incomplete loss of sensation, and operative shock undoubtedly contributed to the high mortality associated with local anaesthesia.

Because the results with local anaesthesia were not satisfactory, the combination of pentothal sodium and nitrous oxide was used. Reduction of the fracture was carried out under pentothal anaesthesia. The operation was then begun, and 50 per cent. nitrous oxide was given, with just enough pentothal to keep the patient in light anaesthesia. Rarely has it been necessary to give more than a total of one gram for the entire procedure. Although some of the poorest operative risks were included in the pentothal group, the mortality rate dropped to 8.8 per cent.

OPERATIVE TECHNIQUE

The use of an orthopaedic fracture table is desirable, particularly when the fracture is badly comminuted or the surgeon is inexperienced in this procedure. In all of the cases

in this series the operations were performed on this type of traction table, with the following technique:

After the patient has been anaesthetized, both legs are fastened in abduction to the traction apparatus of the table. Sufficient mechanical traction is then applied to the affected leg in full internal rotation to produce a valgus reduction.

Portable roentgenograms are now made in the anteroposterior and lateral planes. A curved cassette for the lateral view and a wooden perineal post facilitate roentgenography.

When the adequacy of the reduction has been proved by roentgenogram, the base of the greater trochanter is palpated; and an incision is made, from the trochanter downward for about six inches, on the posterolateral aspect of the thigh. Curving the superior and inferior ends of this incision slightly forward will expedite medial retraction of the soft tissues. The fascia lata is incised, and the shaft of the femur is exposed, either by cutting directly through the vastus lateralis or by reflecting its origin from in front of the greater trochanter and the linea aspera. The periosteum is elevated, and a half-inch hole is carefully drilled through the proximal femoral cortex, care being taken not to shatter the bone and thus complicate the situation by creating a subtrochanteric fracture. This hole is made at, or slightly above, the level of the lesser trochanter.

A Kirschner wire, three thirty-seconds of an inch in size, is now directed through this opening, upward into the neck and head of the femur. Roentgenograms check the position of the wire. If necessary, adjustments are made. By measuring the length of wire protruding from the femoral shaft, the operator can select a blade-plate of the proper length. In most cases, the length of the cervical element of this plate will be three inches or less. With the wire as a guide, the blade-plate is driven into the femoral head.

Fig. 1-A

Fig. 1-B

Fig. 1-A: Mrs. D. R., aged seventy-five. Patient had a comminuted intertrochanteric fracture.

Fig. 1-B: Six weeks after internal fixation with Neufeld nail-plate.

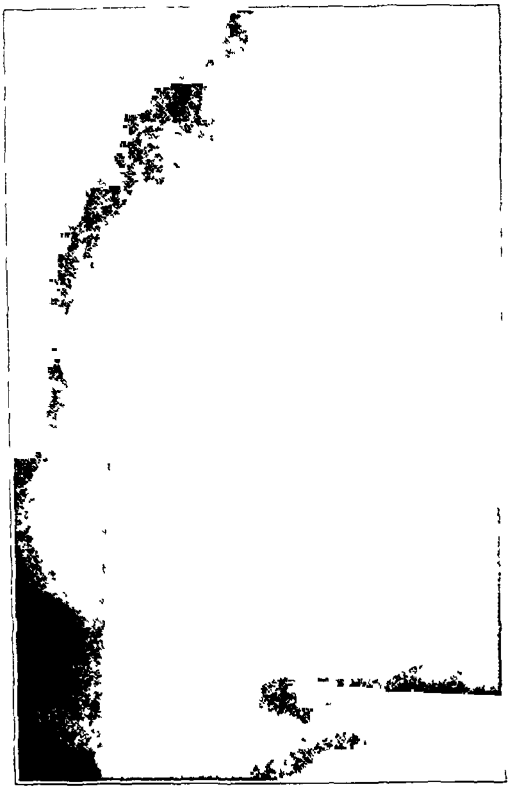

Fig. 2-A

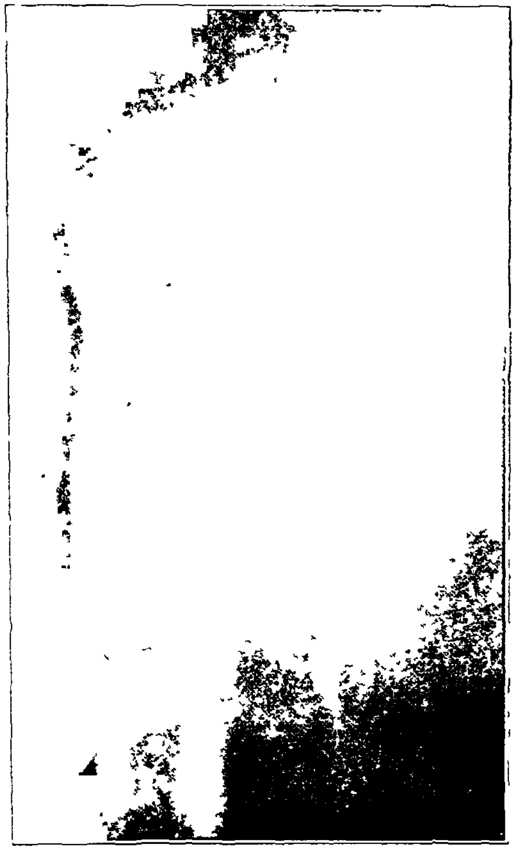

Fig. 2-B

Fig. 2-A: Mrs. M. B., aged seventy. Shows the intertrochanteric fracture, immediately after operation, held in good position by a Neufeld nail-plate.

Fig. 2-B: Roentgenogram taken not quite four weeks later. Bending of the plate has occurred at the upper screw hole. It is possible that this accident might have been avoided if a screw had been placed in this hole.

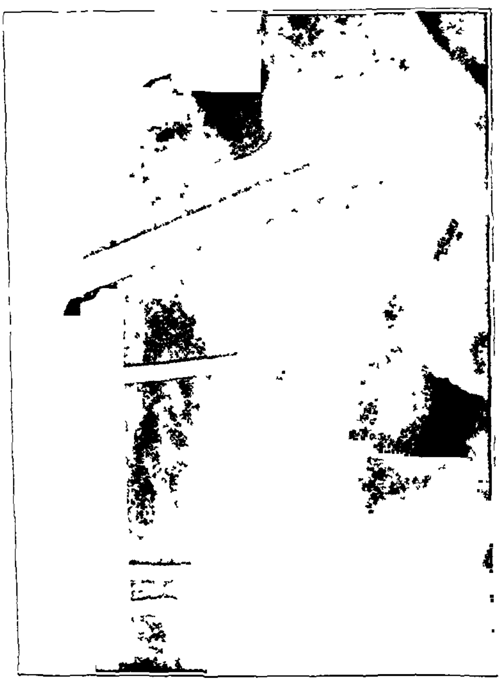

Fig. 3-A

Fig. 3-B

Mr. L. G. This patient began full weight-bearing on his own responsibility, before solid union

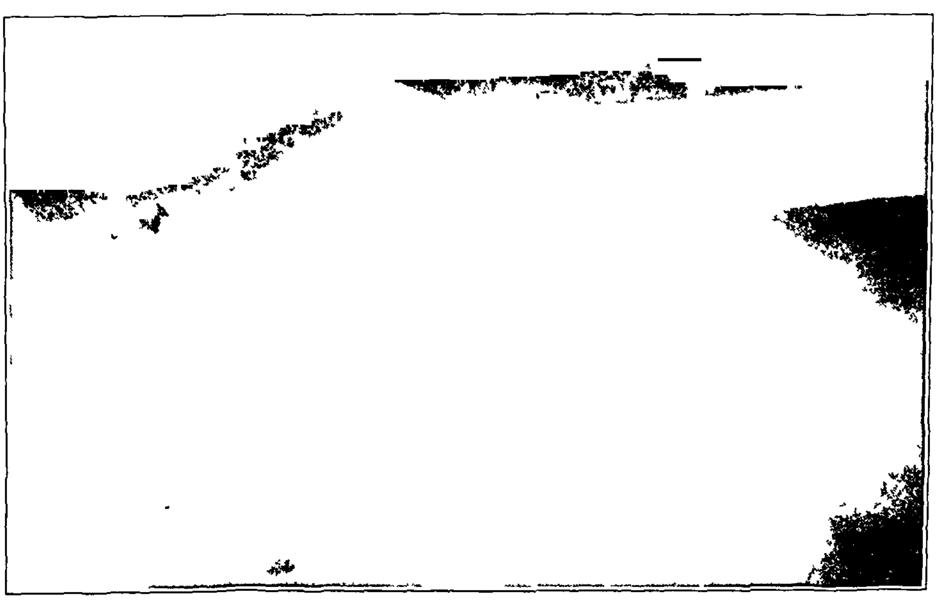

FIG. 4-A

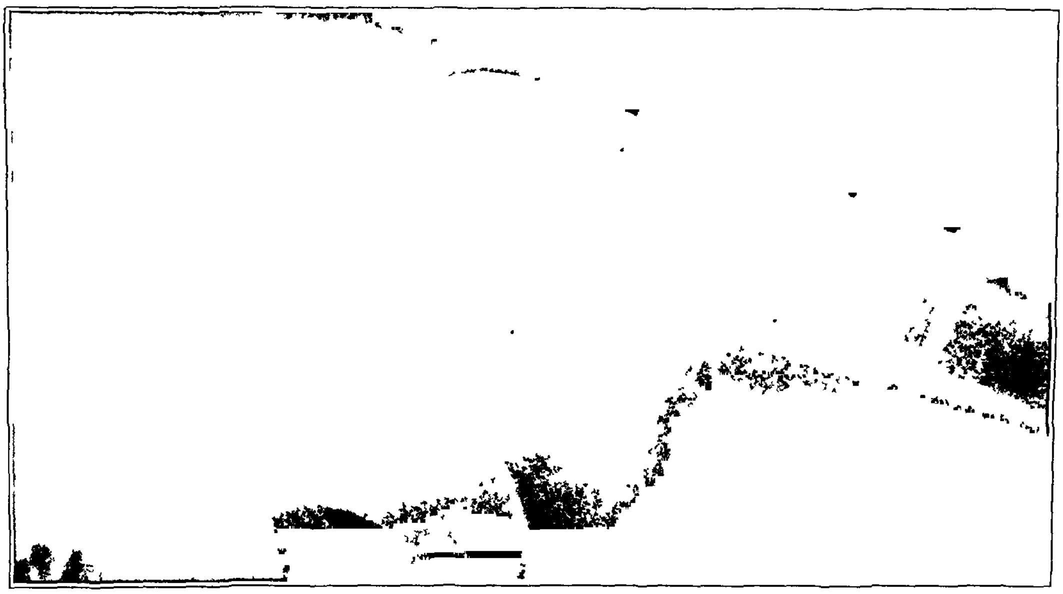

FIG. 4-B

FIG. 4-C

Fig. 4-A: Mrs. A. C., aged seventy-seven. Patient had a comminuted intertrochanteric fracture.

Fig. 4-B. Shows same fracture, five days after operation, with internal fixation by means of the Moore blade-plate.

Fig. 4-C: Three months after operation. Impaction of the inferior portion of the fracture has occurred, causing medial migration of the blade point, with penetration into the hip joint. This complication could have been prevented by using a shorter blade.

A third set of roentgenograms verify the position of the blade If satisfactory, the plate portion is fixed to the femoral shaft with screws, the diameter of which should be at least one sixty-fourth of an inch greater than that of the drill points used. The screws must firmly engage both cortices of the bone. A depth gauge is invaluable in selecting screws of the proper length.

The wound is closed in layers. A heavy pressure dressing with an elastic-bandage spica of the hip is helpful in controlling muscle and bone bleeding after operation.

The operation, including time for roentgenograms, usually requires about one hour and a half. Efforts to shorten the procedure by omitting roentgenographic control will often result in prolonging the operation, and may end in disaster.

Since this series was completed in March 1945, the operation has been performed on seventy-four additional patients on this Service, bringing the total to 177. Beginning in July 1945, a shorter operative method[1] has been used in many instances. The procedure is carried out on an ordinary operating table, without the guide wire, and roentgenograms are taken only to check the final position of the nail-plate. This technique will cut the operating time in half, but should be used only by surgeons who are familiar with the operative treatment of trochanteric fractures.

TYPES OF INTERNAL FIXATION

The type of internal fixation to be used depends upon the choice of the operator and the nature of the fracture. In this series, the Neufeld femoral nail-plate was used in ninety cases, the Moore blade-plate in eight, and the Smith-Petersen nail with the Thornton attachment in five patients. In the authors' hands, the one-piece nail-plate was simpler and easier to use than the combination of the Smith-Petersen nail and the Thornton plate.

The V-shape of the Neufeld nail possesses two advantages: It will not cut out of the femoral head, and it will follow a guide wire more closely than the Moore type. Theoretically, the V would seem to weaken the nail-plate at its angle. In the ninety cases of fixation with the Neufeld nail in this series, the nail-plate did bend at its angle in one case. In two other patients, bending occurred just below the angle, at the upper screw hole (Figs. 2-A and 2-B).

The eight Moore blade-plates used had flat, straight blades. This feature permits adjustment of the angle with special bending irons, and possibly overcomes some of the angle weakness. The flat blade has a tendency to cut out of the head, however; this happened in one case. The newer type of blade-plate, which is convex on its superior surface, will probably overcome this objection, although neither type will follow a guide wire as well as the Neufeld nail.

POSTOPERATIVE CARE

On the day after operation the outer elastic bandage is removed, and the patient who is a poor risk may sit up in a chair. The average patient is allowed up in a chair after about five days. Partial weight-bearing on crutches is begun at the end of six weeks; full weight-bearing is not permitted until there is demonstrable roentgenographic evidence of union. This is usually in about four months.

Quadriceps-setting exercises and flexion exercises of the hip and knee are begun on the first day after operation. Since these exercises are an important feature of the postoperative care, they must be constantly enforced and supervised.

The early freedom of movement possible after operative treatment is a tremendous advantage. The incidence of pneumonia and of decubitus ulcers is reduced markedly, and the psychological stimulus to the patient is inestimable.

COMPLICATIONS

The usual postoperative complications of any surgical procedure tend to occur. As a group, however, these patients have done exceedingly well, despite their age.

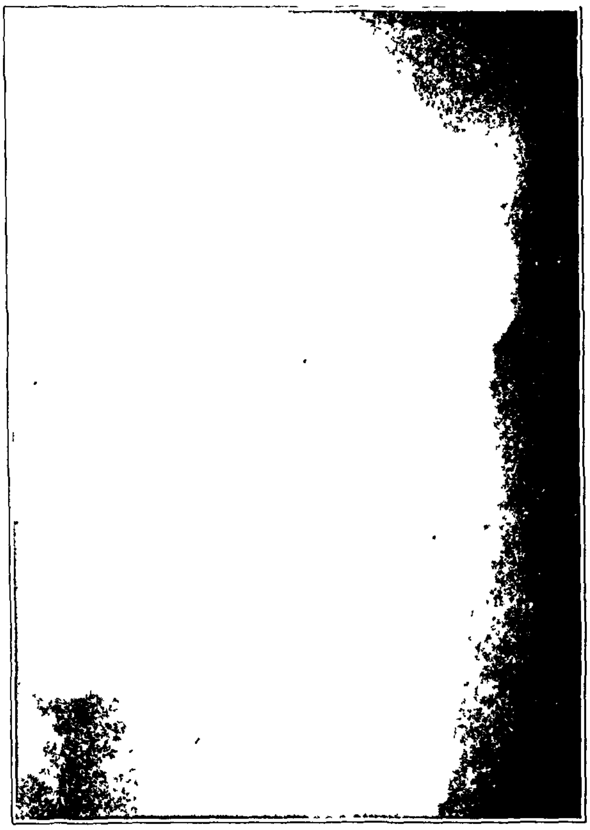

Fig. 5-A

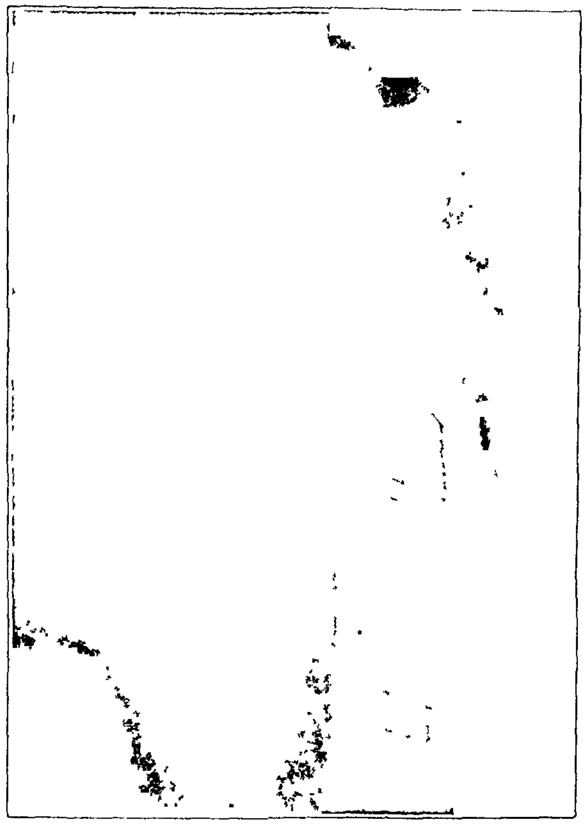

Fig. 5-B

Fig. 5-A: Mr. J. V., aged sixty-eight. Shows intertrochanteric fracture, held in satisfactory position by a Neufeld nail-plate. However, the nail has been placed too near the articular surface of the femoral head.

Fig. 5-B: Roentgenogram, taken six months later, shows the proximal end of the nail protruding into the hip joint. A shorter nail would have averted this frequent, but preventable, complication.

Bending of the nail-plate has been mentioned. In one case, a year after operation, the patient had a serious fall, which caused the nail-plate to break just below the angle, and produced a displaced subtrochanteric fracture. On his own responsibility, another patient began full weight-bearing before union had occurred, and the nail-plate broke three months from the date of operation (Figs. 3-A and 3-B).

An important preventable complication is medial protrusion of the cervical portion of the nail-plate into the hip joint. This happened ten times in the earlier part of this series. Some degree of medial migration of the nail-plate was present in many more cases (Figs. 4-B, 5-A, and 5-B).

Screw fixation of the plate to the femoral shaft prevents extrusion of the nail part from the femoral head. If bone absorption with shortening occurs, the nail tends to increase its penetration of the femoral head. To forestall this difficulty, the authors have adopted the standard that, after the nail has been placed, there should be at least one-half inch between the medial end of the nail and the articular surface of the head of the femur. A nail-plate whose cervical element is longer than three inches will rarely be required.

MORTALITY

In the group of cases studied there were twenty-two deaths,—a mortality rate of 21.4 per cent. In a similar series of operated cases described by Taylor, Neufeld, and Janzen, the mortality rate was almost identical,—21.6 per cent. In sharp contrast to these figures is the mortality rate of 39.2 per cent. reported by Leydig and Brookes for 302 trochanteric fractures treated conservatively at the St. Louis City Hospital several years ago. Harmon describes a mortality of 39 per cent. in 164 patients treated by non-operative methods.

RESULTS

In this series of 103 cases, twenty-two patients died. A follow-up of from one year to two and one-half years was possible on fifty of the eighty-one survivors.

The authors classed as "excellent" the results in those patients who had normal motion of the affected hip and knee, normal gait, no pain, good anatomical restoration by roentgenogram, and ability to return to their usual duties or occupations. In this group there were twenty cases (40 per cent.).

Classified as "good" were the results in those patients who had subjective complaints or slight limp, but walked without a cane or crutch and performed the same occupation as before injury. This classification included eleven persons (22 per cent.).

In eight cases (16 per cent.) the results were considered "fair" because, although weight-bearing on the affected extremity was normal or nearly normal, the patient walked with the aid of a cane or crutch.

Those patients who were unable or unwilling to bear any weight on the fractured extremity were classed as having "poor" results. In this category were eleven, or 22 per cent.

Dealing as we are with a group of individuals whose average age was 70.6 years, and including persons up to eighty-nine years, it is evident that the usual methods of classifying end results of fractures will be necessarily misleading, since they do not consider factors, other than the actual fracture, which might cause poor results. In this series, senile dementia, general debility of the aged, and coexistent disease compromised the results in many cases.

Of the eight patients whose results were considered only "fair" because each used a cane or crutch, most had excellent anatomical results on the basis of physical and roentgenographic examinations. The authors believe that, for at least some of these people, the cane or crutch was unnecessary; and its use was often the expression of habit or desire for security on the part of an elderly person.

Of the eleven cases in which the results were designated as "poor", the authors believe that only one represented a failure of the method; in this patient, marked bending of the nail occurred. In four others the results were due to faulty technique—usually the use of too long a nail—which resulted in subsequent penetration of the nail into the hip joint or the acetabulum. The six remaining poor results were failures, in most instances, for reasons other than the fractures. One patient had rheumatoid arthritis and was confined to a wheel chair. One had metastatic carcinoma. Others had advanced senile dementia and, in spite of good clinical results from the fracture treatment, simply refused to attempt to walk.

Disregarding other factors, of the fifty patients followed, thirty-seven (74 per cent.) had excellent results from the standpoint of good anatomical restoration by roentgenogram, and normal, or nearly normal, motion of the affected hip and knee.

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PAGET'S DISEASE

A Statistical Study of Eighty-Two Cases *

BY FRANK W. NEWMAN, M.D., PHILADELPHIA, PENNSYLVANIA

A review of the case records at the Hospital of the University of Pennsylvania for the fifteen-year period between 1931 and 1945 revealed eighty-two cases of Paget's disease in a total of about 127,000 histories, or an incidence of between 0.06 and 0.07 per cent. Forty-six cases, or 56 per cent., were admitted as medical cases; the remaining 44 per cent. were admitted as surgical cases.

INCIDENCE

Sex and Age

The incidence of the disease shows an almost equal distribution between men and women,—thirty-nine men and forty-three women. The age incidence is shown in Table I, which illustrates and corroborates the well-known fact that Paget's disease occurs predominantly in late middle life. In only three of the cases in this series was the onset within the first four decades of life. The youngest patient was a woman, twenty-one years of age, whose clinical picture was confused by the presence of syphilitic osteitis.

TABLE I

Age at Onset of Symptoms

Years	Number of Patients
Under 40	3
40 to 49	9
50 to 59	21
60 to 69	29
70 and over	20
Total	82

Familial Incidence

None of the patients in this series gave an authentic history of Paget's disease in either the parents or the grandparents. There was, however, one patient whose sister had a large head and may be presumed to have had Paget's disease, although her record is not included here.

Special attention was paid to the incidence of diabetes mellitus, gigantism, and hyperparathyroidism in the family histories. Four patients had family histories of diabetes, but no cases either of gigantism or of hyperparathyroidism were reported in the families of these patients.

CLINICAL FINDINGS

Chief Complaint

Patients with Paget's disease are often not aware of the disease for many years, and their admission to hospitals is often due to unrelated conditions. In this series, only twenty-nine patients entered hospitals because of pain in a part of the body where the bones were found to show pagetoid changes. Two patients complained chiefly of deformity, and eight others had chief complaints related to cranial nerves in areas found

* Read at the meeting of the Philadelphia Orthopaedic Club, March 14, 1946.

TABLE II

CHIEF COMPLAINTS ON ADMISSION

Symptoms	Number of Patients
Pain in the affected bones	29
Visual or auditory disturbances	8
Cardiac disease	6
Epigastric distress or gastro-intestinal disease	6
Urinary-tract disease	4
Diabetes mellitus	2
Bone deformities	2
Other conditions	25
Total	82

to have pagetoid changes. Thus we have a total of only thirty-nine patients, or less than 48 per cent. of the cases, whose chief complaints were closely related to the existing Paget's disease.

In the remaining 52 per cent. of the cases, Paget's disease was an incidental finding. Of this group, there were six patients whose chief complaint was a cardiac condition, six with epigastric distress or gastro-intestinal disease, four with primary urological problems, and two with diabetes (Table II).

Bones Involved

Twelve patients, like those described by Groh, were found to have only one bony structure involved. (The lumbar spine is considered to be "one bony structure" and so is the pelvis.) The pelvis was involved in twenty-nine cases, the skull in twenty-five, the spine in sixteen, the femur in seventeen, the tibia in seven, the humerus in two, and the radius, fibula, and metacarpals each in one case (Table III).

TABLE III

BONES AFFECTED BY PAGET'S DISEASE

Location	Number
Pelvis	29
Skull	25
Spine	16
Femur	17
Tibia	7
Humerus	2
Radius	1
Fibula	1
Metacarpals	1

LABORATORY FINDINGS

Calcium and Phosphorus Levels in Blood Serum: In thirty-six of the patients the calcium and phosphorus in the blood serum were determined. The calcium ranged from 9.4 milligrams to 12.2 milligrams per 100 cubic centimeters. The phosphorus levels ranged from 2.6 milligrams to 6.75 milligrams per 100 cubic centimeters. This is in accord with the findings of Sugarbaker and of Gutman, Tyson, and Gutman, who have stated that the values of serum calcium and phosphorus are rarely disturbed in Paget's disease.

Serum-Phosphatase Levels: Serum-phosphatase levels varied from a low normal of 0.8 Bodansky units to a high of 175 units. Acid-phosphatase levels varied from a normal low of 0.1 unit to 2.0 units; alkaline-phosphatase levels varied from a low normal of 2.6 units to 48.8 units. Although the alkaline-phosphatase determination was made in only nine cases of the present series, a definite elevation was demonstrated in six cases. This test is, therefore, considered the most useful of all laboratory procedures[5,6] in current use in this institution for making the diagnosis of Paget's disease.

Roentgenographic Findings: In almost every case of this series the diagnosis was made on the basis of roentgenographic findings, which were usually described as "coarse trabeculations, osteoblastic lesions, osteolytic lesions, thickening of the cortex, new-bone production, bone destruction, cotton-wool appearance, marked degenerative changes, and areas of increased or decreased density". Often the roentgenologist assumed a familiarity with the typical appearance of the disease and merely stated that the bones showed pagetoid changes. The conditions with which the diagnosis may be most easily confused are metastatic new growths, particularly metastases from the cancerous prostate[11,13].

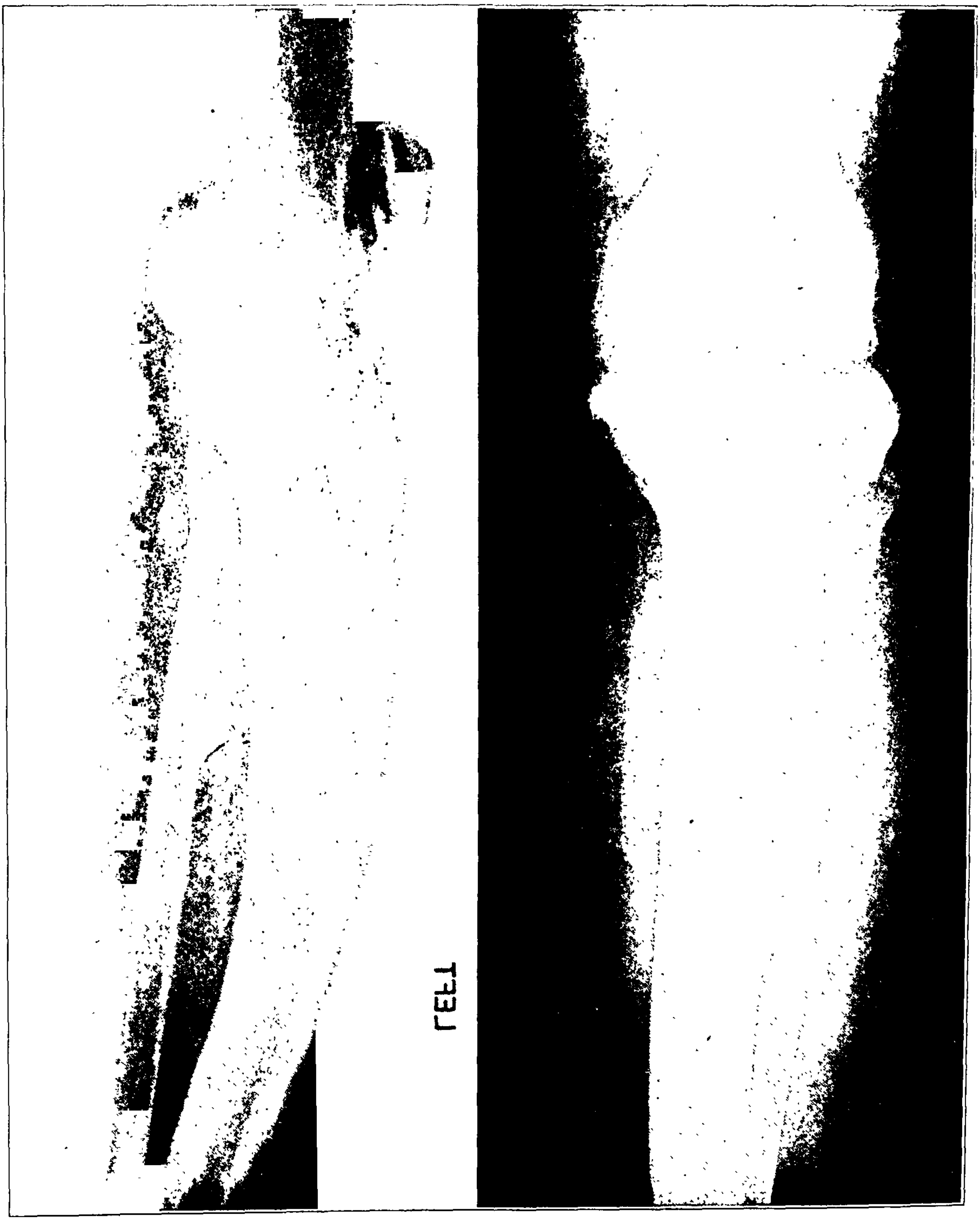

FIG. 1-A

Case 2, Mrs. E. S. Roentgenograms show Paget's disease of tibia, undergoing sarcomatous degeneration.

TABLE IV

BONES IN WHICH FRACTURES OCCURRED

Location	Number
Femur	9
Humerus	4
Tibia	2
Pelvis	2
Radius	1

COMPLICATIONS

The complications of Paget's disease, in the order of their frequency in this series, are as follows: (1) cranial-nerve pressure, (2) fractures, (3) urinary calculi, and (4) sarcomatous degeneration.

Cranial-Nerve Pressure: Twenty-two patients, or 26.8 per cent. of the total number, had defective visual or auditory apparatus. Twenty of these patients had auditory difficulties and two had visual disturbances. Before making any final conclusions as to the etiology of these eye and ear conditions, it would be necessary to have the help of ophthalmologists and otologists in ruling out those due to arteriosclerosis and other causes.

Fractures: Fractures occurred in fifteen patients, or 18.3 per cent. of the total (Table IV). At least nine were pathological,—that is, fractures through bone which, because of Paget's disease, had less than normal strength. From the records available[9], it appears that only one of the fractures failed to unite within a reasonable period of time.

Urinary Calculi: Whether or not calculi in the urinary tract should be considered a complication of Paget's disease is debatable[3]. In the present series this condition occurred in four patients, an incidence of 4.9 per cent.

Sarcoma: The incidence of osteogenic sarcoma or chondrosarcoma in Paget's disease

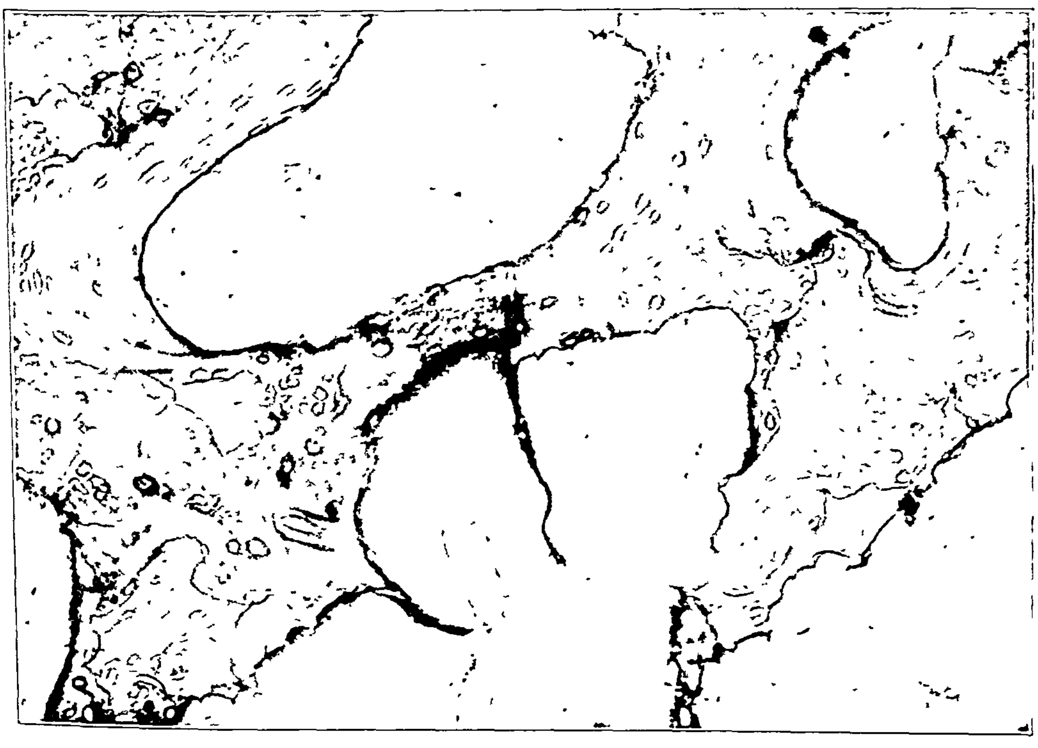

FIG. 1-B

Photomicrograph of biopsy specimen of tibia (×125). Shows bone changes typical of Paget's disease.

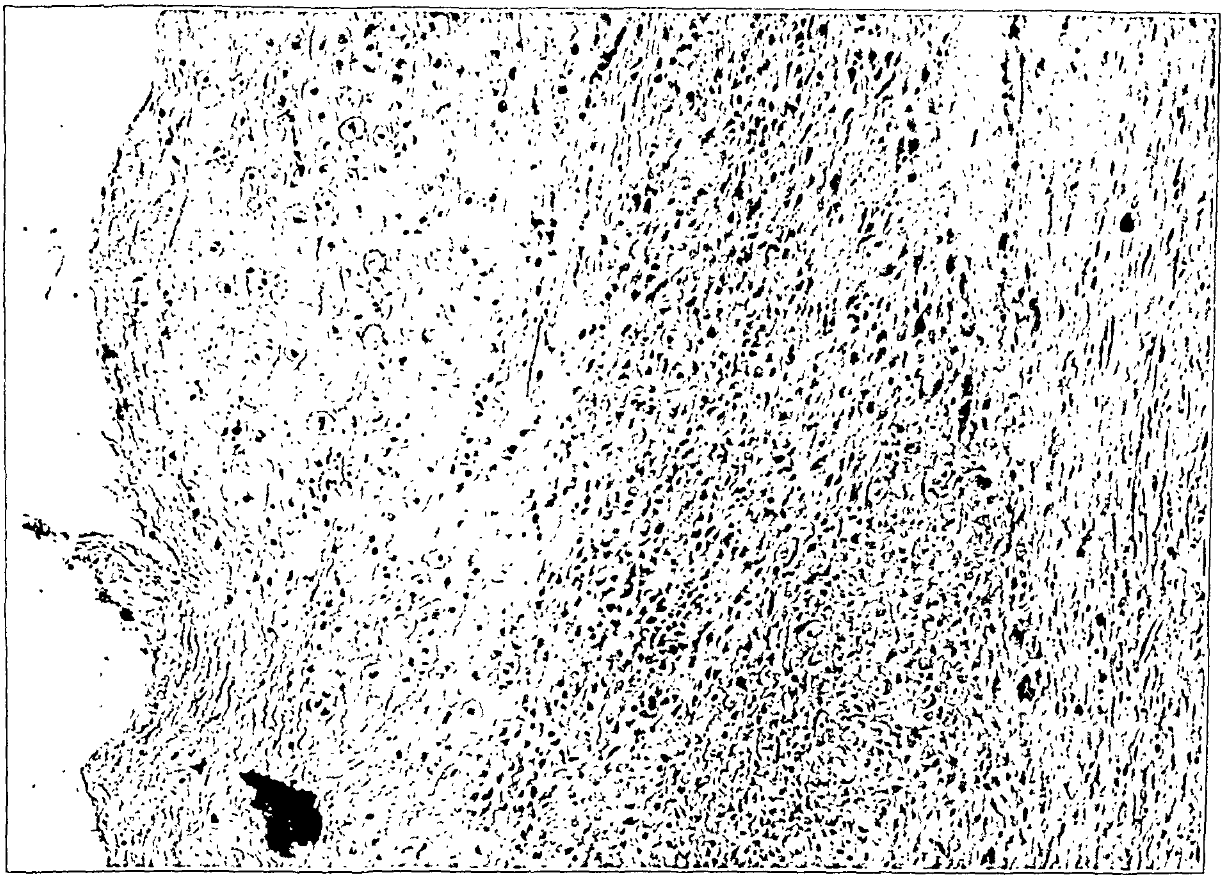

FIG. 1-C
Photomicrograph of biopsy specimen (×100). Shows chondrosarcoma.

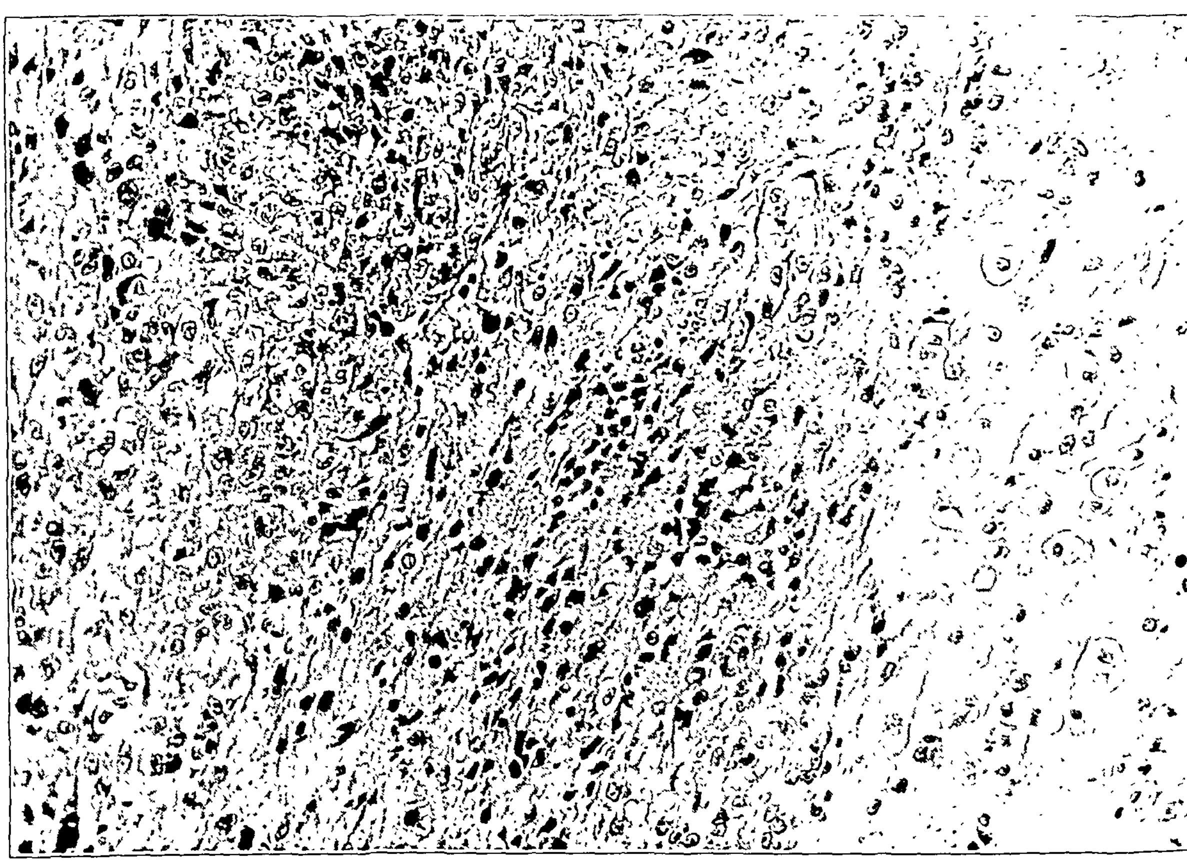

FIG. 1-D
Photomicrograph of biopsy specimen (×242). Shows chondrosarcoma.

is usually said to be about 7 per cent.[1,8]. The incidence in the present series is considerably lower. There were only two cases of proved sarcoma, or 2.4 per cent. A brief résumé of these two case histories follows.

CASE 1. Mrs. J. D. was a white woman, fifty-three years old, who came to the Hospital complaining that a painful swelling of the right knee had persisted for three or four months She had noted no redness or local heat, and had no systemic reaction Before studies were completed, she went to another hospital, where a diagnosis of chondrosarcoma was made and the extremity was amputated Microscopic study of the amputated specimen confirmed the diagnosis of Paget's disease with superimposed chondrosarcoma The patient remained free from further complaints until about eleven months after operation, when a persistent cough again brought her to this Hospital Roentgenograms at this time revealed metastases in the lungs Eight months later the patient died Survival after amputation was about twenty months. No autopsy was done.

CASE 2. Mrs E S was a white woman, seventy-three years old, who came to the Hospital complaining of a painful swelling of the left leg, just below the knee, which had been present for six or seven months Roentgenograms were reported as showing "typical changes of Paget's disease in the upper half of the left tibia". Because of the severe pain and the rapidity of onset, a biopsy was done; a diagnosis of Paget's disease with chondrosarcoma was made The patient refused operation at that time, but has since had the extremity amputated at another hospital It is now three months since the operation, and the patient has had no further complaints

THERAPY

Inasmuch as it is the complications and sequelae of Paget's disease which usually cause the patient to seek medical care, treatment has usually been directed toward relief of the presenting symptoms Auditory and visual disturbances are referred to ophthalmologists and otologists. Fractures have been treated by orthopaedic surgeons and general surgeons, who use standard methods; prognosis as to union is considered to be good[9,10]. Sarcomata have been treated by early amputation whenever possible Roentgenotherapy is usually used when amputation is refused or is impossible, but not many roentgenologists consider it the method of choice If one may judge from the present small series, even amputation must be followed by an unfavorable prognosis

Therapy directed toward relief of symptoms caused by the disease *per se* has in the past been of many kinds, of which only two will be mentioned,—namely, roentgenotherapy and magnesium carbonate.

Roentgenotherapy was given to two patients in this series, both of whom complained of hissing sounds in the ears Both were given two courses of treatment and were still not improved ten or twelve months afterward Formerly this method was used to relieve pain in bones showing pagetoid changes, but in the last five years there have been almost no references to it in the medical literature

Magnesium carbonate was given by mouth to eight patients, six of whom showed symptomatic improvement within one or two months The dose recommended was usually one teaspoonful of the powder two or three times daily, unless the stools became too loose, in which case the dose was decreased to an amount which could be tolerated[2]. Concurrently, a diet low in calcium was recommended The patients who benefited from this regimen found that their complaints were minimum while they conscientiously followed instructions as to medication and diet, but they also noted that their symptoms returned within a few days if they abandoned the regimen

NOTE The author gratefully acknowledges permission to use case histories from the Medical Service of O H P Pepper, M D , and from the Surgical Services of I S Ravdin, M D , Francis C Grant, M D , P Boland Hughes, M D , and P C Colonna, M D

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POSTERIOR APPROACH TO THE SUPEROLATERAL REGION OF THE TIBIA

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Occasionally bone lesions are found in the lateral tuberosity of the tibia or very high in the posterolateral aspect of the tibia. The surgical access to this area is difficult, and the customary procedure includes a temporary resection of the proximal end of the fibula. Fiolle and Delmas described in detail an approach to the origin of the anterior tibial artery, in which the steps of the temporary resection of the distal end of the fibula are described with simplicity and clarity.

Darrach gave a good description of an approach to the posterior aspect of the tibia and the popliteal space, but he was interested primarily in the blood vessels and nerves. Harmon presented a simplified exposure of the posterior region of the tibia for bone-grafting, but specified that the upper fifth of the tibia was not included. Cadenat's anatomical and surgical study of the approaches to the upper and lower extremities gave an all-embracing survey of the entire problem.

The purpose of this article is to present an approach to the bony structures of the upper posterolateral aspect of the tibia. The procedure proved to be useful in several cases, and may be of help to surgeons who are confronted with similar problems.

The anatomy of the area through which the penetration to the bone is obtained was analyzed in thirty cadavera. To complete the description of the surgical approach, discussion of the most common variations of surgical interest is included. With this in view, the following analyses were made:

1. Disposition of the superficial nerves for orientation.
2. Relation of the muscular nerve branches to the muscles of the region and to the tibial and common peroneal nerves.
3. Relation of the origin of the anterior tibial and peroneal arteries to the angle between the tibia and fibula.
4. Variations in the relation of the large vessels to the ring of the soleus.

The arrangement of motor and sensory nerve branches and of the vessels of the popliteal space is such that it can be utilized with profit in the surgery of this region. There are no important nerve branches to the medial side of the popliteal neurovascular bundle between the femoral part of the medial head of the gastrocnemius and the origin of the tibialis posterior on the tibia. Only one small artery crosses this region,—namely, the medial inferior genicular.

A dry, safe field, with exposure of the popliteus, can be obtained if a longitudinal incision is made, penetrating the popliteal region on the medial side of the popliteal artery, and the medial inferior genicular artery is divided and ligated. The popliteus can be divided to expose the underlying bone. With this procedure, the exposure of the upper end of the tibia can be accomplished in a few steps.

DESCRIPTION OF PROCEDURE

A longitudinal incision, four or five inches long, is made in the mid-line, crossing the transverse popliteal crease. The fascia is exposed and the short saphenous vein is identified in the middle of the field, piercing the fascia. To the lateral side of the short saphenous vein, the medial sural cutaneous nerve can be seen through the fascia. The nerve is approximately parallel to the vein. Medial to the vein runs the terminal part of the posterior femoral cutaneous nerve. An incision is now made at the medial side of the posterior femoral cutaneous nerve and the short saphenous vein (Fig. 1).

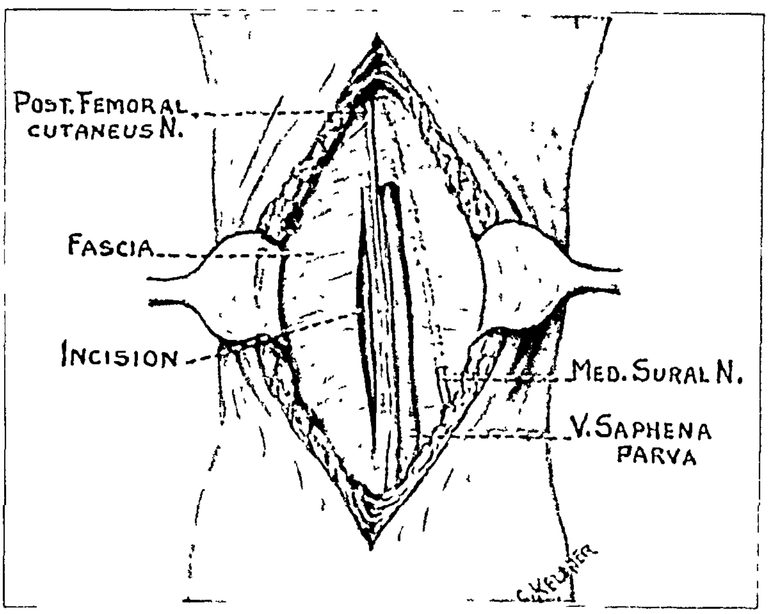

FIG. 1

The sural and the posterior femoral cutaneous nerves help in the orientation of the incision through the fascia. The variations of the posterior femoral cutaneous nerve consist mostly in its termination at points higher or lower than the articular line, or in its breaking up into multiple filaments. The medial sural nerve is sometimes found on the medial side of the short saphenous vein.

The division of the fascia, and its retraction to the sides, exposes the angle of fusion of the medial and lateral heads of the gastrocnemius, which form the distal angle of the popliteal rhombus. The angle of fusion of the heads of the gastrocnemius is divided distally. Retraction of the heads of the gastrocnemius uncovers the shiny long tendon of the plantaris, which indicates the position of the ring of the soleus and, roughly, the line of origin of the soleus on the tibia. Gentle blunt separation locates the popliteal artery as it enters the ring of the soleus. The oblique fibers of the popliteus are visible deep to the artery. On the surface of the popliteus, one can observe the medial inferior genicular artery with its venae comitantes, on its way to the medial aspect of the knee (Fig. 2).

The medial inferior genicular artery is fairly constant in its course. Occasionally it may be found above the popliteus, and infrequently it consists of two trunks instead of one.

Up to the present step, not a single important nerve twig has been encountered in the operative field. The motor nerve twigs to the medial head of the gastrocnemius are never low enongh to interfere with the proximal end of the exposure. The twigs to the soleus are lateral to the popliteal artery. The nerve branches to the upper end of the origin of the tibialis posterior are too low to interfere with the distal end of the incision.

The next step consists in retracting the popliteal artery in a lateral direction and in separating the line of origin of the soleus from the tibia. This is accomplished with great ease with a blunt periosteal elevator. The disinsertion of the soleus, medial to its ring, permits wide lateral retraction of the soleus with the artery, vein, and tibial nerve. The medial inferior genicular artery and veins are divided and ligated. The popliteus is divided across its fibers, stripped from the tibia, and retracted in a lateral direction (Fig. 3).

Although the popliteal artery is not exposed completely when it is identified in this dissection, it is important to be aware of the possible variations which may be encountered in the region. The popliteal artery may divide into its branches near the superior border of the popliteus. Under these circumstances, the posterior and anterior tibial arteries may both lie on the posterior surface of the popliteus, or the anterior tibial artery may pass in front of the popliteus and the posterior tibial artery may pass on the posterior surface of the same muscle. The posterior tibial artery may vary in size and, on rare occasions, may be much smaller than usually represented. However, the variations in the division and size of the popliteal artery do not modify the steps of the approach, if the popliteus is divided on the medial side of the artery and the muscle is separated gently from the underlying tibia.

The retractor which is introduced under the lateral edge of incision of the popliteus after its division produces traction and simultaneously protects the large vessels and the important nerves, which are all located lateral to the incision.

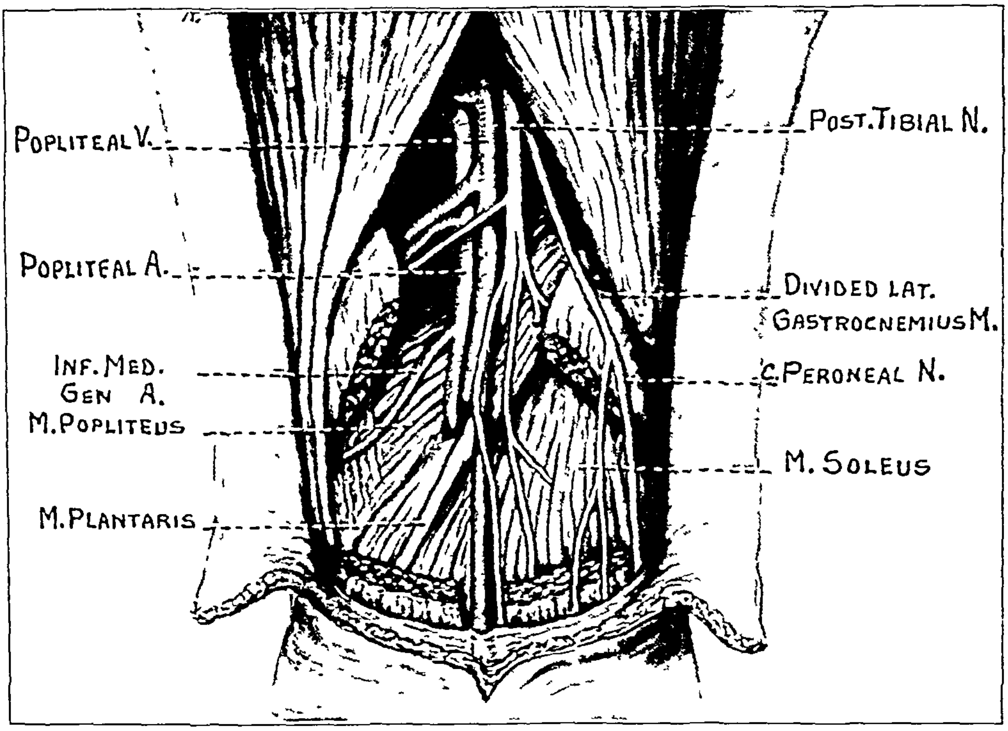

FIG. 2

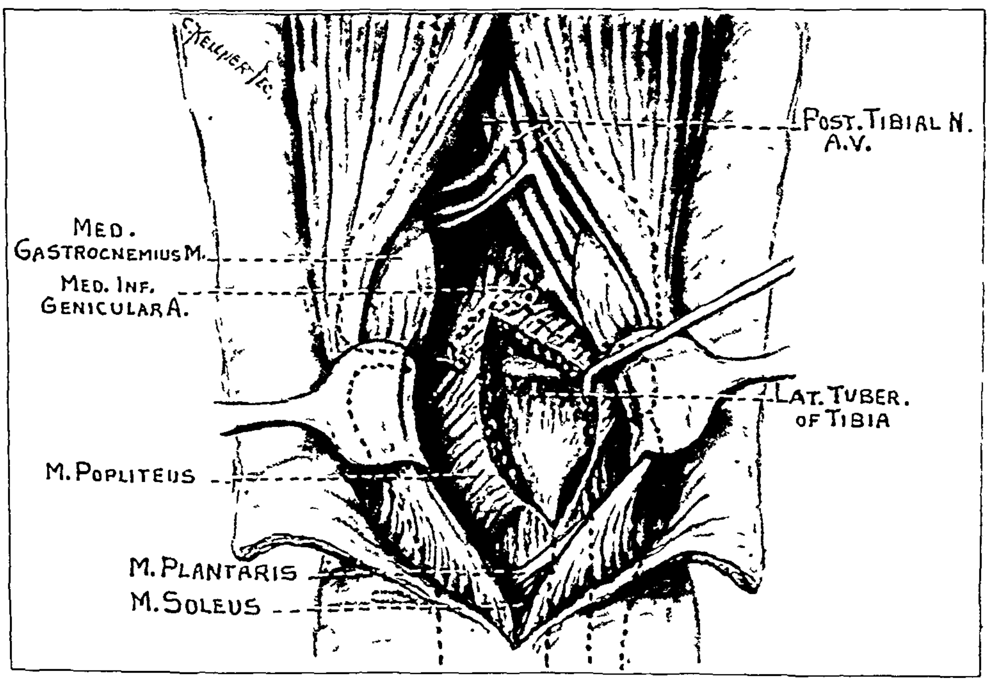

FIG. 3

The angle formed by the tibia and the upper end of the fibula can also be exposed. The anterior tibial artery originates in this area and must be avoided. It has been found that the anterior tibial artery almost never passes through the interosseous membrane at the apex of the angle formed by the tibia and fibula. The distance between the apex of the angle and the artery varies from approximately 2 5 to 4.5 centimeters. This relationship permits ample room for approach to the tibiofibular angle.

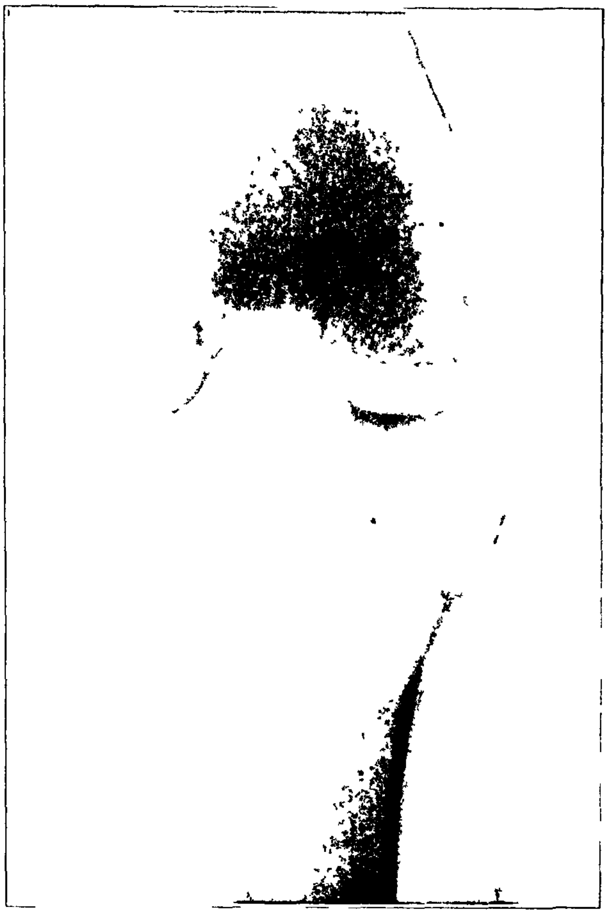

Fig. 4-A

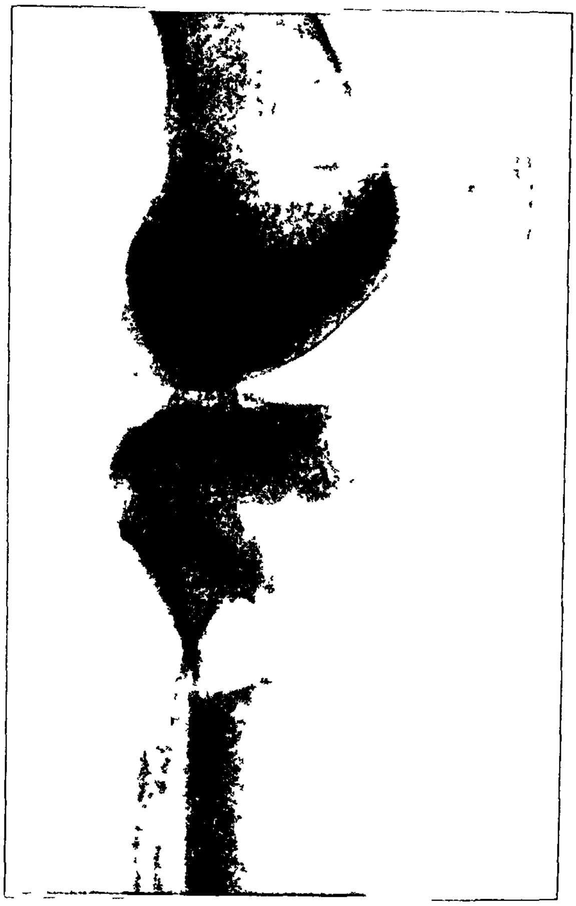

Fig. 4-B

Postoperative roentgenograms show bone defect at site of previous osteoma.

Upon completion of the operation, the structures are permitted to fall back into place. The fascia is the only structure which requires suturing.

The advantages of the procedure described may be summarized as follows:

1. Temporary resection of the fibula is avoided;
2. There is only slight interference with anatomical structures;
3. The postoperative closure is simplified, because only suture of the fascia is required.

The only disadvantage of this approach is the relative depth of the operative field. The position of the fibula, in a more posterior plane than the tibia, restricts somewhat the lateral retraction, but this does not interfere with proper exposure of the field.

ILLUSTRATIVE CASE

H. K., thirty-two years old, was admitted to the Hospital on September 18, 1945, complaining of pain in the anterolateral region of the left knee of three years' duration. Roentgenographic examination suggested an osteoid osteoma of the upper posterolateral region of the tibia. The lesion was excised on September 22, 1945, under roentgenographic control, through the posterior approach already described. Postoperative roentgenograms showed a bone defect, corresponding to the site of the osteoma (Figs. 4-A and 4-B). The patient made an uneventful recovery and resumed his normal activities in one month.

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A SURGICAL PROCEDURE FOR REPAIR OF RECURRENT DISLOCATION OF THE SHOULDER JOINT

A Preliminary Report *

BY CAPTAIN EDWARD H. CROSBY
Medical Corps, United States Naval Reserve

In the United States Navy during World War II, it was found that recurrent dislocation of the shoulder was encountered more frequently than in civilian practice, and that it made the sailor or marine unfit for full combat duty. The frequent failure of the usual methods of surgical treatment for recurrent dislocation of the shoulder led to a study of the literature and the development of a new operative procedure.

Chronic dislocation of the shoulder produces apprehension in a sailor or marine, because the shoulder may become dislocated at any time, causing pain and complete disability. In some cases, the individual is able to reduce the dislocation himself; but, in jungle warfare, even temporary disability may be fatal. The soldier with such a disability is unfit for full combat duty.

The many operations described in the literature for repair of recurrent dislocation of the shoulder can be classified into three groups: (1) operations altering the skeletal structure of the shoulder joint, using bone graft to augment the anterior rim of the glenoid cavity, or so placed as to prevent the humeral head from leaving the glenoid fossa; (2) operations on the capsule of the shoulder joint, either repairing injury to the capsule or adding fascia to supplement the capsule; and (3) ligamentous, tendon, or muscle suspensions.

In the first group of operative procedures, the skeletal structure of the shoulder joint is altered. In the second group, the torn capsule of the joint is repaired, either by plicating the capsule or by adding fascial transplants to strengthen the capsule. In the third group of operative procedures, either the anatomical relation of ligaments, tendons, or muscles already present in the shoulder girdle is altered, or such tissues are transplanted to the shoulder to suspend the humeral head in the glenoid cavity.

The treatment for recurrent dislocation of the shoulder at a Naval Hospital is influenced by many factors which do not disturb the civilian surgeon. If the condition existed prior to enlistment, no operative procedure is warranted unless it will return the man to full duty. A physical defect is often used as an excuse to avoid duty, and an operation done while the man is in the Service may supply the necessary objective condition which is desired by the patient. If the injury is acquired in the Service, the malingering element is reduced.

The author performed a series of fourteen operations on thirteen patients for the repair of recurrent dislocation of the shoulder, by a technique not previously described. This technique used a three-inch incision over the bicipital groove, separating the anterior deltoid muscle. The transverse humeral ligament was cut, and the tendon of the long head of the biceps was retracted with a tape. The cartilage on the floor of the groove was removed, the synovial membrane on the tendon was cut away, and the tendon was anchored in the bicipital groove with three No. 3 nylon sutures, passed through holes drilled in the posterior crest of the groove. The transverse humeral ligament and the outer edge of the tendinous capsular cuff were closed. When possible, the capsular cuff was plicated with No. 3 nylon sutures. Exercises were started and increased according to tolerance, after three weeks' immobilization of the affected shoulder in a sling and a bandage. Five of the

* Based on a scientific exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1946.

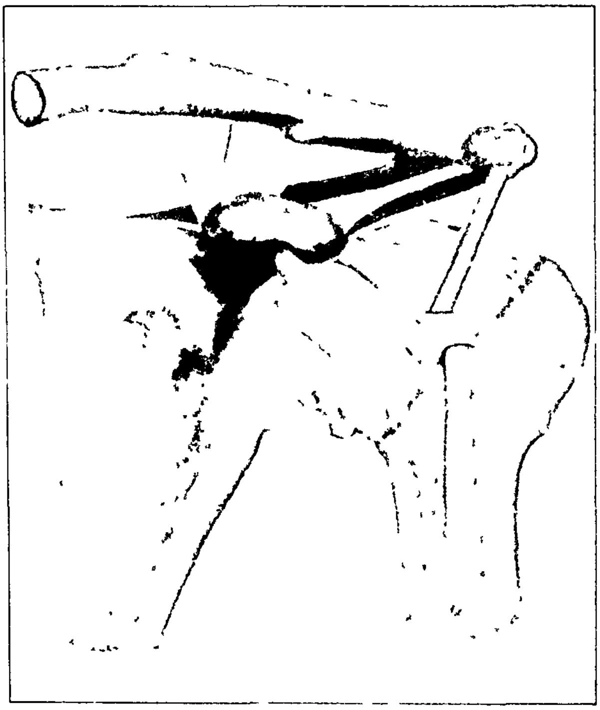

FIG. 1

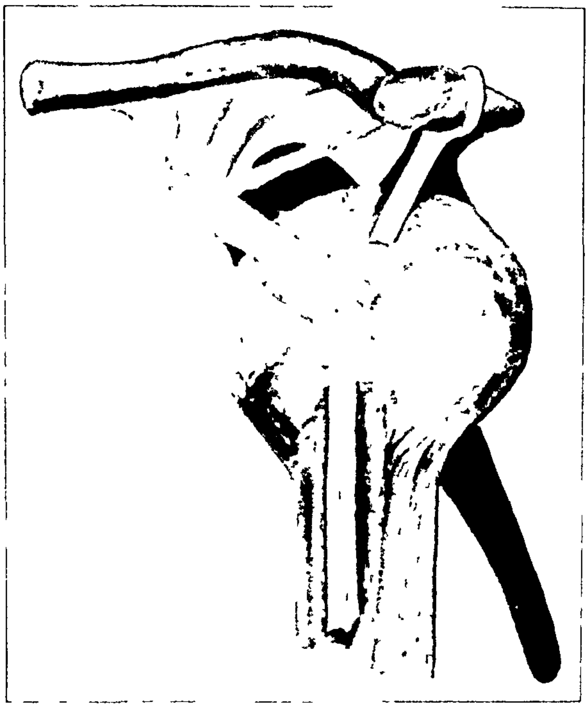

FIG. 2

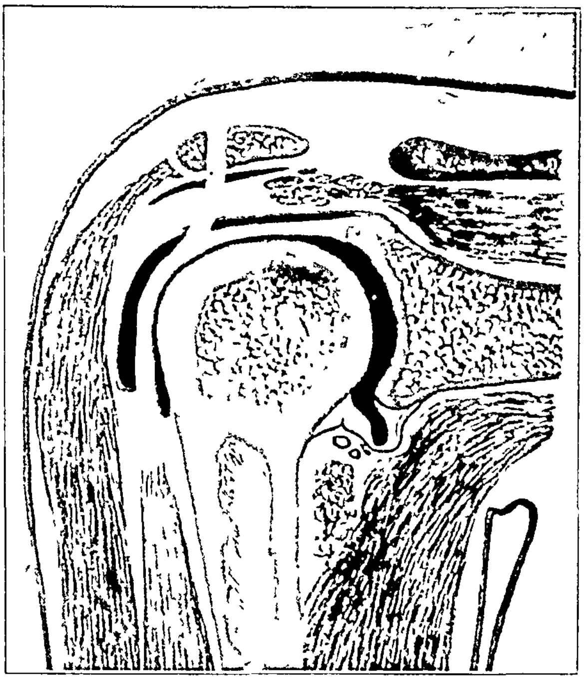

FIG. 3

Fig. 1: Front view, showing the origin of the tendon of the long head of the biceps, changed from the supraglenoid tubercle to the acromion. The tendon passes out of the joint through a hole cut in the anterosuperior capsule.

Fig. 2: Side view, showing the origin of the tendon of the long head of the biceps, changed from the supraglenoid tubercle to the acromion. The tendon passes in a straight line from the proximal end of the intertuber groove of the humerus to the acromion.

Fig. 3: Sagittal section through the shoulder at the level of the tendon of the long head of the biceps, showing how changing the origin from the supraglenoid tubercle to the acromion prevents dislocation of the shoulder.

patients in this series (including one case which was bilateral) returned to active duty with the Fleet Marine Force in the Pacific; four were returned to limited duty; and four had a recurrence of the dislocation after the operation. The author performed the second operation on the four patients with recurrences. At the second operation, the tendon of the long head of the biceps muscle was found to be firmly anchored in the bicipital groove, and the tendon was intact. At this operation, a transverse hole was drilled through the greater tuberosity, and a hole was placed in the acromion from above downward. Fascia lata was passed through these holes, drawn tightly, close to the capsule, and sutured to itself and to the capsule. The fascia was spread over the anterior capsule and was sutured to strengthen the capsule. Six to ten months have passed since the second operation, and at the present time the shoulders are secure and solid, with practically normal motion.

It was felt that the procedure of anchoring the tendon of the long head of the biceps in the bicipital groove was sufficient for normal civilian function, especially in individuals beyond the age of active athletics, and that this procedure was preferable to other operations because of its simplicity. However, the operation did not give sufficient strength to

the shoulder to permit all patients to return to the strenuous activity of the Fleet Marine Force. Consequently, the following operation was performed on thirty-two shoulders with recurrent dislocations (two patients had bilateral recurrent dislocations), and has fulfilled all requirements.

OPERATIVE TECHNIQUE

1. A longitudinal incision is made from just above and medial to the tip of the acromion process, downward about four inches toward the mid-cubital fossa of the elbow. The fibers of the anterior deltoid muscle are separated to expose the capsule of the shoulder joint and the transverse humeral ligament.
2. The capsule is cut from a point just above the upper end of the bicipital groove, medially and slightly upward over the course of the biceps tendon for a distance of three-quarters of an inch. When the capsule is opened with retractors and the arm is pulled downward, the superior part of the joint is exposed, showing the origin of the long head of the biceps tendon at the supraglenoid tuberosity. A tape is placed under the tendon for the purpose of traction.
3. The tendon is cut close to its origin from the supraglenoid tubercle, causing little or no bleeding, and the cut end is removed from the joint.
4. Lateral traction on the freed tendon exposes the cartilage on the floor of the bicipital groove. This is removed with a sharp curette. The tendon is pulled upward and its synovial membrane is removed from that part of the tendon which passes through the bicipital groove.
5. The free end of the tendon is passed through a small hole cut in the superior part of the capsule, and carried under the deltoid muscle to the acromion process in as nearly a straight line as possible (Figs. 1 and 2).
6. The superior surface of the acromion is exposed, and a hole, large enough to receive the free end of the biceps tendon, is made through it from above downward. The hole is placed about one-quarter of an inch from the edge of the acromion so that a strong bridge of bone remains. The free end of the tendon is passed through this hole from below upward, and about one-half inch of the tendon is allowed to extend beyond the acromion. The end of the tendon is divided so that the anterior half can be brought forward and downward, and can be sutured to the trunk of the tendon just before it enters the hole in the acromion. The posterior half of the divided tendon end is carried backward and sutured to the periosteum of the acromion (Fig. 3). The elbow is flexed and the arm abducted during this step, so that there is very little tension on the biceps tendon.
7. The incision through the capsule, which parallels the superior margin of the subscapularis tendon as it merges into the capsule, is plicated with a double row of interrupted No. 1 nylon sutures.
8. The tendon is anchored in the bicipital groove by a deep No. 1 nylon suture, passed through the transverse humeral ligament, incorporating the biceps tendon.
9. The shoulder joint is passed through its complete range of motion to ensure adequate fixation of the tendon and the plicated capsule. The deep sutures over the acromion are placed through the tendon so that fixation of the tendon is made firm, and the wound is closed anatomically.
10. The shoulder is immobilized in a sling and a modified Sayre's bandage for three weeks.
11. After the three weeks of immobilization, gradually increased exercises are begun.

SUMMARY OF CASES

Operations were performed in thirty-two cases,—thirty men and two women. Their ages ranged between eighteen years and thirty-four years. Twelve dislocations occurred in the right shoulder; sixteen occurred in the left shoulder; and two were bilateral. In

eight cases the first dislocation occurred during combat fighting, in thirteen while engaged in athletics, in seven from a fall, and in one while rolling a barrel; in three cases the cause was not remembered. The treatment after the first dislocation varied: No treatment was given in fifteen cases, a sling was used for less than three weeks in twelve cases and for three weeks or more in four cases, and treatment was not remembered in one case. Preoperative examination of the shoulder showed limited and painful motion in thirteen cases, muscle atrophy about the shoulder in three, and subluxation of the joint in ten; all had deep tenderness over the front of the shoulder joint. Roentgenographic findings were negative in twenty-four cases, showed subluxation in three, calcium deposits in the subdeltoid bursa in one, a shallow glenoid fossa in one, a groove in the head of the humerus in one, roughness of the anterior glenoid rim in one, and roughness in the greater tuberosity and acromion in one.

All of the operations except one were done on Marine personnel. Eight cases have been followed for more than one year; the remaining cases have been followed for more than six months. In one case in the series, the operation failed, because the new attachment of the tendon pulled away from the acromion when the patient threw a football, four weeks after operation. In twenty-seven of the remaining thirty cases, the patients returned to full combat duty. The other three patients could not return to full duty, although the shoulder was stable. Follow-up letters have been received from two of the three patients, stating that they are doing heavy work without discomfort. In the remaining case there has been no further dislocation, and a follow-up letter from the patient's mother states that he does not want to work.

COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT

The Nature of the Traumatic Lesion and Effective Methods of Treatment with an Analysis of Forty-One Cases

BY MAJOR MARSHALL R. URIST

Medical Corps, Army of the United States

Although incomplete dislocations of the acromioclavicular joint are frequent, complete dislocations are uncommon, and even orthopaedic surgeons of wide experience seldom see very many cases in their personal practices. The largest single series on record consists of less than a dozen cases. The lack of large single experiences may reasonably be assumed to account for a number of facts: that the pathological basis of complete dislocation of the acromioclavicular joint is still incompletely understood; that in spite of the small number of recorded cases, more than thirty-five conservative methods and at least twenty-eight operative methods of correction have been advocated; and that very few end results of treatment by any measures are recorded in the literature.

The existing situation in respect to complete dislocations of the acromioclavicular joint is the justification for the present communication, which has for its purpose (1) the presentation of forty-one patients treated by a single observer, this apparently being the largest single series to be recorded; (2) clarification of the anatomicopathological basis of the lesion; (3) an evaluation of the conservative and operative methods currently advised for the correction of the dislocation; and (4) the description of an improved method of conservative treatment.

ANALYSIS OF CASES

The forty-one instances of complete dislocation of the acromioclavicular joint reported in this communication were observed in the 802nd Hospital Center while it was stationed at Blanford, England, and at the 97th General Hospital while it was stationed at Frankfurt, Germany. The series does not include primary subluxations or sprains. All patients with minor subluxations, observed in the European Theater of Operations, were treated in forward medical units or hospitals and could return to duty within a month, the results apparently being in agreement with those obtained by Thorndike and Quigley with various types of strappings. The evidence is to the effect that sprains, if left alone, become reduced spontaneously within a week or less, and heal well.

All the patients were strong, active young soldiers, within the same age group. Their injuries, all of which were caused by great violence, were variously sustained in combat, parachute jumps, hazardous engineering operations, and traffic accidents; a few were sustained on the football field. Twenty-three injuries were acute and were recognized early. As a result, the patients were promptly evacuated from the combat zone and arrived in fixed hospitals for treatment within a few hours after injury, if transportation was by air, and within ten days, if transportation was by water or by rail. The majority had received first aid or primary treatment shortly after the injury. In the remaining eighteen cases, the injury was unreported, unrecognized, or untreated for periods ranging from several weeks to eighteen months after it had occurred. In this group of cases the orthopaedic problem was often complicated by such war-related conditions as combat fatigue and conversion reactions, focused upon non-disabling and non-symptomatic lesions. Eleven patients, representing both groups, had associated fractures of various portions of the clavicle, the acromion process, and the coracoid process.

ANATOMICAL STRUCTURE AND POSSIBLE VARIATIONS OF THE ACROMIOCLAVICULAR JOINT

The acromioclavicular joint, which overlies the shoulder joint and the motion of which is synchronous with the motion of the shoulder joint, appears to be unique in man. The

relationship between the structures which make it up—the clavicle and the acromion process—is normally maintained by the acromioclavicular and coracoclavicular ligaments. The coracoclavicular ligaments form a synosteosis of a particular type termed syndesmosis, which indicates that the skeletel elements are bound together by a continuous band of elastic connective tissue. Anatomical studies of the shoulder area, as well as numerous reports of anomalous conditions in this region, show that the coracoclavicular syndesmosis either is a metamorphosed joint or represents a trend toward the development of a diarthrodial joint between the coracoid process and the inferior surface of the clavicle. About 1 per cent. of random roentgenograms of the shoulder[51,57] show well-developed coracoclavicular diarthrodial joints. The acromioclavicular joint itself is a true diarthrosis, because the articular surfaces of the acromion process and the outer end of the clavicle are separated by a joint cavity and are surrounded by a capsule reinforced with ligaments. Since in man there is no motion of the coraco-acromial syndesmosis (represented by the coraco-acromial ligament), its functional significance is not clear. It can be sacrificed without any effect on the action of the shoulder[13].

The possible variations in the form of the acromioclavicular joint were studied in 100 sample roentgenograms of the shoulder, which were unselected except that the patients had no symptoms referable to the shoulder and that the variations were present bilaterally. All films were taken by the standard Army method, so that variations cannot be explained by changes in technique. The formal study of these sample films was undertaken to confirm the impression of the frequency of variations which the writer had received as he examined large numbers of films for other orthopaedic conditions.

TABLE I

CLASSIFICATION OF ANATOMICAL VARIATIONS IN THE ACROMIOCLAVICULAR JOINT IN 100 RANDOM ROENTGENOGRAMS OF THE SHOULDER

Description of Joint	Per Cent.
1. The articular surface of the clavicle overrides the articular surface of the acromion.	49
2. The articular surfaces of the acromion and clavicle are nearly vertical and lie in the same plane.	27
3. The inferior margin of the articular surface of the clavicle underrides the superior margin of the acromion.	3
4. The articular surfaces are incongruent, and the clavicle overlies the acromion.	9
5. The articular surfaces are incongruent and are not in contact at any point.	6
6. The articular surfaces are incongruent, and the inferior margin of the clavicle underrides the superior margin of the acromion.	6

From this study the following facts were ascertained: The articular surfaces vary in size and form. Occasionally they are separated by a meniscus attached to the superior acromioclavicular ligament. The meniscus may be a blade of fibrocartilage extending perhaps halfway into the joint (as in Case 36) or it may form a complete disc, dividing the joint into two parts. Occasionally no diarthrosis is present, as in Case 39 of this series, in which the joint was represented merely by a pad of fibrous tissue attached to the outer end of the clavicle, and no evidence of an articular cavity was noted. Such instances are described in standard texts of anatomy[72] and are not uncommon.

The joint surfaces are often incongruent, such abnormalities almost always being bilateral. The outline of the articular surface of the acromion process may correspond to the outline of the clavicle, but often it does not. In some individuals no part of the clavicle opposes the end of the acromion, and for all practical clinical purposes the patient has a congenital subluxation or relaxation of the acromioclavicular joint. The clinical prominence of the acromioclavicular joint is usually determined by the degree of overriding of the acromial end of the clavicle. In some individuals, the joint surfaces may lie in a vertical plane (Fig. 3) or the acromion may partly overlie the clavicle (Fig. 7), although in the majority of cases there is usually some overriding of the clavicle on the acromion

Fig. 10). These and other variations observed in the 100 cases studied roentgenographically are classified in Table I. In addition to this classification, the acromioclavicular joint an vary in the shape of the distal end of the clavicle, which may be bulbous, square, usiform, flattened, or cylindrical.

As this study indicates, relatively seldom does the acromioclavicular joint, as observed oentgenographically, correspond to the classical anatomical description. Normally the rticulation is constructed of parts, formed at different stages of the morphogenesis of the ypical diarthrosis. There is some evidence, although the observation is still disputed, that he outer end of the clavicle is formed in the embryo by intramembranous ossification[90]. Be this as it may, variations from the anatomical norm are reasonably accounted for by he fact that the evolutionary development of the acromioclavicular joint was frequently nterrupted.

MECHANISM OF INJURY AND THE TRAUMATIC LESION

With few exceptions, the patients in this series were unable to state at just what point he shoulder had received the blow which resulted in acromioclavicular dislocation. Only wo had abrasions or ecchymosis to indicate the point of contact of the force,—in Case 36 falling steel beam struck the acromion process, and in Case 40 the area over a fracture of the clavicle was discolored. In the majority of cases, it was assumed that a blow on the lorsum or the anterior aspect of the shoulder had forced the scapula downward or backvard[13,74,89]. Cases have been recorded in which the scapula was forcibly drawn downward nd anteriorly by a sudden change in the position of a heavy burden being carried[54], and thers are on record in which the force may have been transmitted through the arm, with he result that the coracoid process came into contact with the clavicle and thus pried the oint apart[54,100].

It has been generally assumed, since the pioneer surgical work of Cadenat in 1917 nd of Watkins in 1925, that a complete dislocation of the clavicle cannot occur without earing of the conoid and trapezoid ligaments[1,9,54,62,85], and illustrations in current textbooks[49,83,86] are based on this concept. There is, however, very little evidence in the literature to support it[62,98]. It is easily understood that, when the distance between the coracoid process and the clavicle is greatly increased in the injured shoulder, as compared with the intact shoulder, the coracoclavicular ligaments are correspondingly stretched or sprained, but they are not necessarily torn[57]. If the force was transmitted through the arm, the injury might be sustained by the joint capsule alone, the ligaments themselves suffering no damage.

The deformity in unreduced dislocations of the acromioclavicular joint is maintained by the pull of the trapezius on the distal end of the clavicle, by gravity, and by the absence of counterpull by the aponeurosis of the anterior portion of the deltoid. When the arm on the affected side is weighted, the scapula and so the acromion process are drawn downward and forward, causing the gap in the joint to be increased both anteroposteriorly and superoinferiorly. In doubtful cases this manoeuvre is useful in accentuating the lesion for roentgenographic purposes.

EXPERIMENTAL OBSERVATIONS

The following experimental studies were carried out on cadavera to confirm impressions as to the mechanism of injury, derived from observations made at the operating table:

1. On the first shoulder, the coracoclavicular ligaments were transected through a stab incision, after which the acromial end of the clavicle was grasped through the skin with bone forceps and tested for motion. Motion was not in excess of that on the intact opposite side, and subluxation was not produced when strong traction was applied to the arm on the transected side.

2. On the second shoulder, the superior acromioclavicular ligament and the entire

joint capsule were transected through an incision overlying the joint. After this, it was possible to produce incomplete disarticulation of approximately 50 per cent.

The incision was then carried around the outer end of the clavicle in the shape of a U, and the attachments of the deltoid and trapezius muscles to the clavicle were divided. When the end of the clavicle was drawn upward and posteriorly, complete disarticulation resulted; but when it was pulled straight upward, only incomplete disarticulation was produced.

Transection of the coracoclavicular ligaments was then performed on the same shoulder, as described under heading No. 1, after which the entire outer end of the clavicle could be disarticulated upward farther than when only the attachments previously mentioned had been cut.

3. On the third shoulder, the trapezoid ligament was dissected and divided, as well as the deltoid and trapezius attachments to the clavicle and the superior acromioclavicular ligaments. The clavicle could then be drawn posteriorly or upward until it was completely dislocated.

4. On the fourth shoulder, the same preparation was carried out as described under heading No. 3, except that the conoid ligament was sectioned instead of the trapezoid. The same results were achieved as on the third shoulder, except that the acromial end of the clavicle could be dislocated farther upward.

5. On the fifth shoulder, the same preparation was carried out as on the third and fourth, except that the coraco-acromial ligament was sectioned, first alone and then in combination with each of the other ligaments. No effect on the stability of the acromioclavicular joint was observed.

Observations similar to those described have been reported by Poirier and Rieffel, Delbet and Mocquot, and Cadenat, among others; and their interpretations of the results are in agreement with that of the writer, except for one important difference: The observations just recorded emphasize the leading role played in complete dislocation of the acromioclavicular joint by the joint capsule and the attachments of the deltoid and trapezius muscles. When these structures were severed, to simulate the tearing or stretching which occurs in them with dislocation, complete dislocation of the outer end of the clavicle was possible without injury to the conoid or trapezoid ligaments. It is true that rupture of the conoid and trapezoid ligaments allowed greater displacement of the clavicle, but the picture was altered quantitively, not essentially. Section of only the conoid or of only the trapezoid ligament had no specific effects, and there is no physiological analogy between these structures and the cruciate ligaments of the knee.

Cadenat reminded his readers that tone and action of the surrounding muscles in the living subject probably alter the relationships of the parts in the functioning joint, and the individual ligaments may have different degrees of elasticity, required for synchronizing the motions of the clavicle with those of the surrounding parts.

EXAMINATION OF RESECTED JOINTS

It was possible to study the process of healing after complete dislocation of the acromioclavicular joint in nine cases in which resection of the distal end of the clavicle was necessary at intervals varying from three weeks to one year after injury. A variety of treatments had been employed in these cases, all of which had resulted in incomplete correction. No fresh clinical material was available for examination, since, in accordance with directives of the United States Army Medical Department, all cases must be managed conservatively and healing must be permitted for a sufficient length of time to establish the existence of a residual disability before surgical treatment is instituted.

In each case the coracoclavicular ligaments were found to be stretched and elongated, but all had healed in complete continuity. The texture upon palpation varied between cicatricial induration and bony hardness. Elongation and scarification were proportional

to the distance between the outer end of the clavicle and the coracoid process, but bony tissue was not always identified.

Healing of the joint capsule in each case had been associated with increased thickening, up to a maximum of four millimeters.

Other changes were as follows: (1) Obliteration of the articular surfaces and replacement with fibrous connective tissue occurred in five cases; interposed flakes of cartilage, fibrocartilage, and necrotic hyalinized material were interpreted as the remnants of capsular ligament and meniscus, separated at injury in two cases. (2) Osteocartilaginous loose bodies were found in one case (Fig. 13). (3) Osteo-arthritic changes, such as bone eburnation and marginal spurs, occurred in five cases. In two cases evidence was found of subchondral compression fractures of the clavicle and acromion processes, which had not been evident in the roentgenograms.

The observations on healed ligaments are corroborated by the findings of Gurd on fresh cases; this author also mentioned that complete dislocation of the clavicle occurred in one case without complete rupture of the coracoclavicular ligaments. Other observers, however, describe stretched[11] or ruptured[10,18] ligaments at open operation for repair of the conoid and trapezoid ligaments with fascia lata.

The data obtained by observation of both clinical and experimental material make it seem most likely that the clavicle can become completely dislocated without rupture of the coracoclavicular ligaments. In occasional cases the trapezoid ligament is stretched, and in rare cases it is grossly ruptured. Microscopically, of course, the individual fibers of the conoid and trapezoid ligaments are necessarily torn during injury. The observations made in this study further suggest that the capacity of these ligaments for healing and repair is excellent, and is sufficient to aid reconstitution of the joint relationships.

SPECIAL TESTS OF VALUE DURING TREATMENT

Although the clinical picture of fresh acromioclavicular separation is familiar to all surgeons, special tests that apply during the course of the injury deserve emphasis.

(A) *Widening of the Joint Space*

In some cases (Fig. 1-E) in which the outer end of the clavicle is characteristically above and posterior to the acromion process, it may be possible apparently to reduce the dislocation and to obliterate the deformity without difficulty, but the roentgenogram may show measurable separation or widening of the joint space (Figs. 3 and 4). In such cases, if both clavicles are outlined with the examining finger tips, it can easily be ascertained that, while the upward displacement of the dislocated clavicle is corrected, there is still slight posterior displacement. Further manipulations may correct the position in a fresh case, but are not likely to be effective in older cases.

(B) *Ballottement*

Observations in this series suggest that, although the number of cases is too small to permit definitive statements, if free floating of the distal end of the clavicle (ballottement) is observed at the end of three weeks or more of conservative treatment, this form of treatment is not likely to be effective. The phenomenon was observed in four cases in this series and was striking in Cases 4 and 5. Both were instances of posterior displacement and were treated conservatively in the splint devised by the writer, which will be described later. In each case, ballottement was evident when the shoulder strap of the splint was turned back at the end of three weeks and the distal end of the clavicle was pushed downward and anteriorly to attempt an adjustment. At the end of six weeks, when the splint was removed, the dislocation was only partially corrected, and subluxation was evident in the course of three weeks of rehabilitation. When the distal end of the clavicle was later excised, because of complaints of pain and a feeling of instability, fibrous connective tissue, capsular ligament, and torn meniscus were found interposed between the joint surfaces;

TABLE II

Significant Data in Eighteen Complete Dislocations of the Acromioclavicular Joint Treated by Early Reduction and Immobilization for Six Weeks *

Case No.	Type of Joint	Position at Four Weeks	Ballottement at Four Weeks	Calcification in Coracoclavicular Ligaments	Cosmetic Result	Residual Symptoms
1	Overriding	Excellent	+	+	Excellent	None
2	Overriding	Excellent	+	0	Good	Pain
3	Overriding	Good	0	+	Excellent	None
4	Overriding, nearly vertical	Good	0	+	Fair	None
5	Nearly vertical	Wide joint space	+	0	Subluxation	Pain
6	Incongruent, vertical	Wide joint space	+	+	Slight subluxation	Pain
7	Overriding	Excellent	0	+	Perfect	None
8	Overriding	Excellent	0	0	Perfect	None
9	Overriding	Excellent	0	0	Excellent	None
10	Incongruent, vertical	Excellent	0	+	Excellent	None
11	Overriding	Excellent	0		Excellent	
12	Overriding	Slightly wide joint space	0	+	Excellent	None
13	Overriding	Slightly wide joint space	0	0	Excellent	None
14	Overriding	Excellent	0	0	Excellent	None
15	Overriding	Excellent	0	0	Excellent	None
16	Vertical	Good	-	+ With avulsion fracture of the clavicle	Slight subluxation	Pain
17	Vertical	Good	-	0	Slight subluxation	Slight pain
18	Nearly vertical	Good	+	0	Subluxation	Slight pain

* In Cases 16, 17, and 18 the patients were seen ten days after injury, at which time they were transferred from adhesive strappings to the author's splint. A fracture of the acromion process was associated with the dislocation in Case 4, of the coracoid process in Case 7, and of the clavicle (avulsion type) in Case 16.

they obviously prevented accurate reposition and presumably caused the free floating of the clavicle observed before operation. The same findings were also noted at operation in three other cases.

The test for ballottement of the clavicle is particularly informative after three weeks, when uncomplicated or well-reduced dislocations ordinarily become stable as the result of healing of the capsular ligament and repair of the attachments of the deltoid muscle; and a positive test, as has been stated, suggests that conservative treatment may be ineffective.

(C) *Evolution of Symptoms*

It is important that symptoms complained of in instances of recurrent or untreated subluxation be carefully evaluated. At the end of three weeks, when joint effusion and periarticular swelling and tenderness have disappeared, a complete dislocation with overriding and with no contact of the clavicle and the acromion process is not likely to be very painful. Most soldiers minimize the symptoms, which may, however, be aggravated if the men are called upon to do hard work. In a certain (unknown) proportion of such cases, residual subluxation following conservative treatment of complete dislocations is associated with pain and annoying crepitation, with or without limitation of motion of the shoulder joint. Under these circumstances, the validity of the symptoms must be studied carefully. Men in civil life are likely to disregard the deformity and to refuse surgical treatment; while

TABLE III

SIGNIFICANT DATA IN ELEVEN COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT SEEN LATE AND NOT TREATED

Case No.	Type of Joint	Primary Treatment	Days of Healing	Calcification in Coracoclavicular Ligaments	Osteo-Arthritis	Residual Symptoms
19	Overriding	Hunkin's cast	56	0	+	Subluxation
20	Vertical	Watson-Jones's adhesive splint	58	+	0	Subluxation
21	Congruent, vertical	Watson-Jones's adhesive splint	35	0	+	Subluxation
22	Overriding	Jones's humeral splint	34	+	+	Subluxation and Erb-Duchenne palsy
23	Underriding	Stimpson's adhesive splint	395	+	+	Subluxation
24	Vertical	Velpeau adhesive splint	270	+	+	Dislocation
25	Overriding	No treatment	35	+	+	Dislocation
26	Vertical	Velpeau bandage	70	+	0	Dislocation
27	Overriding	None	42	0	+	Dislocation
28	Incongruent, overriding	None	300	0	0	Subluxation
29	Incongruent, overriding	None	330	0	+	Subluxation

women will accept or ask for surgery, because they regard the protrusion of the bone on the shoulder as unsightly.

The following objective tests are useful in confirming the validity of the patient's complaints:

1. When the patient leans against a wall, thus pressing the inferior angle of the scapula firmly and sharply on the posterior aspect of the thorax, pain in the acromioclavicular joint may be elicited.

2. When the patient elevates the arm, pain is elicited in cases complicated by synovitis, fibrous ankylosis, or arthritis of the joint. Full elevation of the arm may be impossible.

3. When the patient shrugs the shoulder, rotates the arm internally, or carries a weight, palpable crepitations or subjective grating sensations are accentuated. (The standard weight, used to amplify the deformity for a roentgenographic record, is a thirty-five-pound bucket of sand in each hand.)

4. Pain or ankylosis of the joint may prevent crossing the elbows anteriorly (adduction).

TABLE IV

SIGNIFICANT DATA IN FIVE COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT TREATED PRIMARILY BY VARIOUS METHODS

Case No.	Type of Joint	Primary Treatment	Cosmetic Result	Residual Symptoms
30	Overriding, nearly vertical	Skeletal traction	Excellent	Pain
31	Overriding	Skeletal traction	Excellent	Slight pain
32	Overriding	Phemister's trans-articular wire	Slight subluxation	None
33	Overriding	Coracoclavicular screw	Slight deformity	None
34	Overriding with fracture of acromion and coracoid processes	Thoracobrachial spica, 90 degrees abduction	Excellent	Pain and stiffness

In determining the necessity for further treatment, it is also desirable to take into consideration the character and structure of the acromioclavicular joint. In this series it was found that patients who had no symptoms after conservative treatment (Table II) often presented the overriding type of clavicle, whereas patients showing complications (Table IV) frequently presented vertical or partially undergliding joints. Subchondral compression fractures were found in two cases in this group (Cases 5 and 41). Although the number of cases is too small for positive statements, it may be possible that individuals with vertical or undergliding joints are more likely than those with other types of joint to respond poorly to conservative treatment and to develop complications.

TREATMENT

The purpose of treatment in dislocations of the acromioclavicular joint is twofold,— to secure anatomical reposition and to relieve symptoms. These objectives are interrelated; but anatomical restoration of the joint does not always relieve symptoms, which may originate in residual damage to the articular surface and the joint capsule, whereas a patient with a poor anatomical result may have no symptoms at all. Furthermore, although clinical examination and roentgenograms may show the bones in perfect position after immobilization for the proper length of time, the dislocation will recur, when the splint is removed, if healing has not reestablished the continuity of the periarticular ligaments.

Since Thorndike and Quigley's plea for conservatism in the management of dislocations of the acromioclavicular joint, it has become established that a very high percentage of incomplete dislocations or subluxations can be managed by the use of only the simplest of adhesive dressings. On the other hand, failure to obtain a satisfactory cosmetic result in some instances of subluxation, as well as the occurrence of painful sequelae and of limitation of motion, is equally well known.

An analysis of the literature, as well as the results in this series of forty-one cases of complete dislocation of the acromioclavicular joint, indicates that from 10 to 20 per cent. of the cases treated conservatively with improved methods show residual subluxations or some degree of disability as the result of pain, instability, and limitation of joint motion.

Professor E. S. Cooper of San Francisco, who was apparently the first surgeon to operate for this lesion, "ventured" to suture the acromion process to the distal end of the clavicle on a woman who "had a nervous desire to get rid of the deformity amounting almost to insanity". Although such an operation was then a very daring thing, he reported that to admit the atmosphere to bones is not a source of injury to the patient, and was "satisfied to rest the justification of its [the procedure's] claims to value upon the statistic of results in future operations".

At present, as in Cooper's time, experienced clinicians frequently find that complete dislocation of the outer end of the clavicle is difficult to manage by conservative methods[14,16,49,53], and that some degree of deformity is almost the rule[32,57,68,89] if operation is not done. The selection of the cases which require surgery after conservative treatment, correctly applied, has failed to achieve results, must be based on an evaluation of the individual patient and of his complaints. The type of operation and the time at which it should be undertaken are less open to argument. To speak categorically, surgery is necessary in untreated cases, in neglected cases, and in properly treated cases which improve so little under conservative measures within three or four weeks that it is unwise to require the patient to continue such therapy longer (Table III).

MANIPULATION AND REDUCTION

The following methods of manipulation are known to reduce most acromioclavicular dislocations, and they were used in various cases in this series to correct the deformity before the application of splints:

1. The surgeon depresses the prominent distal end of the clavicle by means of pressure by the thumb over a small felt pad[89].

2. As an alternate method, the surgeon elevates the scapula and acromion process by elevation of the flexed elbow[23].

3. The patient, while supine, is instructed (a) to throw his shoulders back[70]; (b) to abduct the arm 90 degrees or more[61]; or (c) to hyperextend the head, in order to relax the pull of the trapezius on the outer end of the clavicle[13].

4. The patient, while erect, is instructed (a) to throw the shoulders upward and backward[20,60,93]; or (b) to abduct the shoulder 90 degrees or more[49].

Combinations of Methods 1 and 2 are most widely applied to obtain the desired position for immobilization in a brachioclavicular splint. In Methods 3 and 4, the surgeon instructs the patient in the necessary manoeuvres, or may carry them out on him, as is most convenient.

The experience of all observers is that, although maintenance of the dislocated joint in position for the necessary six weeks is difficult, reduction of the dislocation is usually easy. There are, however, several obstacles to complete reduction in the occasional case, which are not revealed by casual inspection. The clavicle, for instance, may slide into position rotated on its long axis (Case 5), or may lie posterior to the acromion process even when held down at the correct level by manual pressure (Case 4). As pointed out previously, the cause of these difficulties was found, in cases later treated by excision of the distal end of the clavicle, to be due to interposition of the meniscus, frayed ends of capsular ligament, and flakes of articular cartilage.

If the acromioclavicular joint is ruptured, it is possible to overcorrect the deformity by pushing the clavicle down below the level of the acromion process. In two cases in this series (Cases 8 and 18), immobilization in this position resulted in an excellent cosmetic and functional result.

CONSERVATIVE METHODS

Following reduction of the dislocation, various types of splints and other apparatus have been used to maintain the position in which the lesion would heal, it being generally agreed that the time required for this process is six weeks.

Bandages: Slings and bandages, although very valuable for first aid, are seldom used in the definitive treatment of dislocations of the acromioclavicular joint. The brachioclavicular slings and bandages devised by Pilcher, Desault, Velpeau, Jones, and Lund are difficult for modern surgeons to apply[1], because they have had little or no practice with them, and the bandages must be painfully tight if they are to be effective for any length of time[14]. Copher revived the bandage technique[93] with his description of a figure-of-eight elastic bandage so applied as to elevate and retract the shoulders.

Adhesive Dressings and Strappings: Adhesive brachioclavicular slings have been described by Stimson, Sayre, Nichols and Smith, Gordon, and Martin. Watson-Jones's adhesive sling is a modification of the bandage devised by Sir Robert Jones. Thorndike and Quigley's method involves the application of strappings over the shoulder and across the chest to depress the clavicle, but does not elevate the scapula.

The disadvantage of all methods requiring the use of adhesive strapping is that perspiration and skin irritation make the patient extremely uncomfortable and are real obstacles to treatment for the required length of time. Improved techniques, which include the use of protective felt boards[4,89], coaptation splints[39], elastic fabrics[30], and elastoplast[5], still do not obviate the necessary removal and reapplication of the dressing, which are almost as unpleasant for the physician as for the patient.

Suspension: Barr, Metz, and Caldwell[14] suspended the arm in a Balkan frame in 90 degrees or more of abduction on the affected side, and this is a valuable method for bedridden patients who must be treated for other injuries or complications. All the evidence

FIG. 1-A

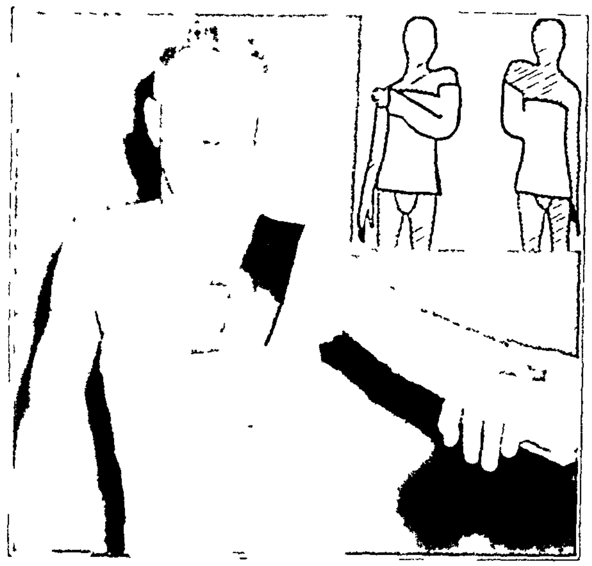

FIG. 1-B

Fig. 1-A: Case 1. Shows separate application of padded arm and body plasters.

Fig. 1-B: The elastic shoulder strap is made of a strip of salvaged inner tube. The rubber is stretched tightly over the clavicle, with its ends doubled back on themselves between layers of plaster bandage, to maintain constant pressure. The next step (completed in Fig. 1-C) elevates the scapula, as in the method of Dillehunt (inset)[23,31].

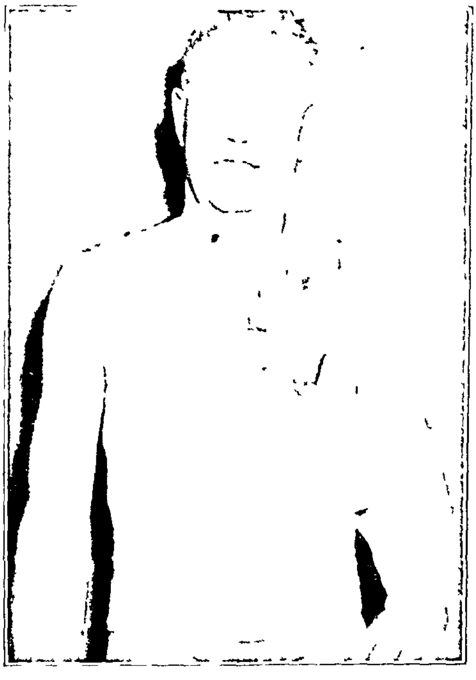

FIG. 1-C

FIG. 1-D

Fig. 1-C: Arm section of plaster has been fixed to body section and elevated to a position which holds the shoulder on the affected side one or two inches higher than the shoulder on the intact side.

Fig. 1-D: Continuous pressure is maintained by wide area of thickly padded shoulder strap. Immobilization can be effected comfortably and without interruption for six weeks by this method. Support of body plaster on iliac crests gives countertraction and aids in maintaining elevation of arm on body.

in the literature, however, is to the effect that these methods, which have the advantage of simplicity and the disadvantage of inconvenience, have not proved to be sufficient to effect repair in cases of complete dislocation of the acromioclavicular joint.

Harnesses and Braces: Currie, Warner, Rawlings, and Giannestras devised harnesses which follow the pattern of the brachioclavicular sling. Shaar and Howard described harnesses equipped with elastics to compress the acromial end of the clavicle. Roger Anderson's abduction brace differs from all others in that it elevates the shoulder by means of a padded cradle under the axilla, and depresses the clavicle by means of an attached shoulder strap.

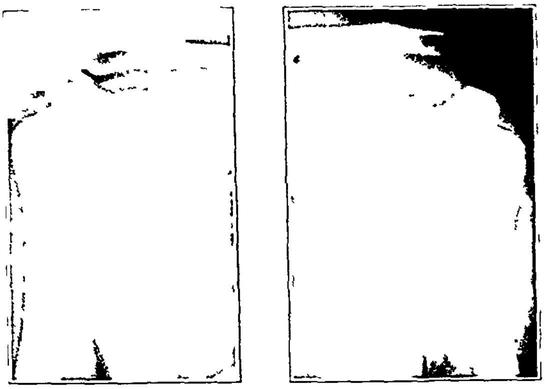

FIG. 1-E

FIG. 1-F

Fig. 1-E: Roentgenogram showing the dislocated clavicle before treatment. This is the overriding type of joint.

Fig. 1-F: Roentgenogram of dislocated left shoulder immediately after reduction to anatomical position in author's splint. Note slight overcorrection of dislocation, as shown by comparison of distances between coracoid process and clavicle in the reduced left joint and the intact right joint (Fig. 1-E).

The efficiency of all of these appliances is proportional to the amount of supervision and instruction given the patient. The efficiency of the Roger Anderson brace is obviously good, and in the tropics[75] such forms of treatment are desirable because they afford greater comfort for the patient. On the other hand, the cost and availability of fitted apparatus of any kind always limits its use.

Plaster-of-Paris Splints: Innumerable splints have been devised for the correction of acromioclavicular dislocation by plaster techniques, all of which have both advantages and disadvantages. Hunkin's splint[101] is a loose plaster torso cast, suspended from a webbed shoulder strap. Gibbens's is a hanging arm cast, suspended from an elastic band over the shoulder, the principle being that the weight of the plaster will depress the outer end of the clavicle. In both this method and that of Hunkin, the effort to maintain reduction is relaxed whenever the patient lies down.

Key and Conwell recommended a thoracobrachial spica with 90 degrees of abduction, and Hart recommended a cast with 45 degrees of abduction; in the latter method a webbed shoulder strap maintains position, partly by abduction and partly by pressure. The surgeons who advise abduction do not state its effect on the anteroposterior position of the clavicle when the joint capsule is ruptured, but there is probably some posterior displacement which must be corrected by pressure on the outer end of the clavicle. When the dislocation is complicated by a fracture of the acromion process, the joint surfaces, or the coracoid process, the shoulder spica[49], as well as the brachioclavicular cast devised by Böhler, is essentially a compromise to secure comfortable immobilization for the patient (Case 5). Trynin and Legg also devised plaster brachioclavicular casts, Legg's being a Velpeau bandage (reported by Girard), the efficiency of which is increased by the addition of an adjustable elastic shoulder strap. The pressure of the shoulder strap in brachioclavicular slings, without elevation of the scapula, especially in techniques which utilize gravity, is usually too much to be tolerated by the skin for six weeks, although moderate compression of the outer end of the clavicle, preferably by an elastic strap, is necessary to produce perfect anatomical realignment.

Dillehunt's torso cast elevates the acromion process, until it is aligned with the distal end of the clavicle, by fixing and elevating the arm on the side of the chest (Fig. 1-B). This counteracts the pull of the trapezius and at the same time cancels the weight of the arm, thus achieving reduction and immobilization with very little force.

The splint devised by the writer for the correction of complete dislocation of the acromioclavicular joint incorporates the most desirable features of the splints devised by

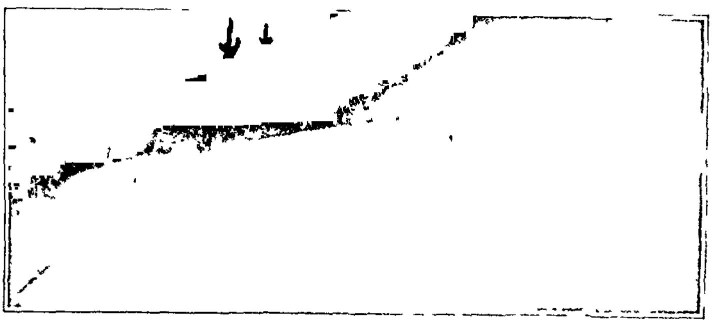

Fig. 2

Case 8. Roentgenogram of left acromioclavicular dislocation, sustained in a motorcycle accident, after reduction and overcorrection in author's splint. Arrows indicate points of main pressure of shoulder strap on clavicle, which do not show clearly in film.

Dillehunt, Shaar, Howard, and Legg. In particular, as in Dillehunt's splint, elevation of the scapula is maintained by anchoring the body plaster to the iliac crests, to provide the necessary counterbalance. The defect in all of these splints is that they fail to depress the clavicle below the level of the acromion process. This feature is desirable, because it overcorrects the deformity. It is necessary to the best cosmetic and functional end result, and is provided in the author's modification (Figs. 1-F and 2) by the elastic shoulder strap, which supplies the necessary clavicular depression without excessive cutaneous pressure.

The modified splint should be applied early, before organization of the hematoma and healing in the tissues around the lesion is under way. It must be realized that the splint has the disadvantage of restricting movement of the arm or of the chest, which some surgeons prefer to avoid[1,35,99].

END RESULTS OF CONSERVATIVE TREATMENT

Fifteen soldiers with complete dislocations of the acromioclavicular joint, who had been evacuated promptly from forward areas in first-aid bandages or temporary adhesive strappings, were treated by application of the writer's splint (Figs. 1-A to 1-E, inclusive, and Fig. 2) for the required six weeks. In no instance was any untoward effect on the elbow observed when the splint was removed. Twelve patients returned to duty as completely cured after a period of physical therapy and rehabilitation. Another patient, in whom subluxation developed without pain or limitation of motion, also returned to unrestricted military duty, which did not increase the deformity. The two remaining patients (Cases 5 and 6) presented subluxations associated with symptoms after several days of physical therapy, following the removal of the casts, and eventually were subjected to surgical treatment.

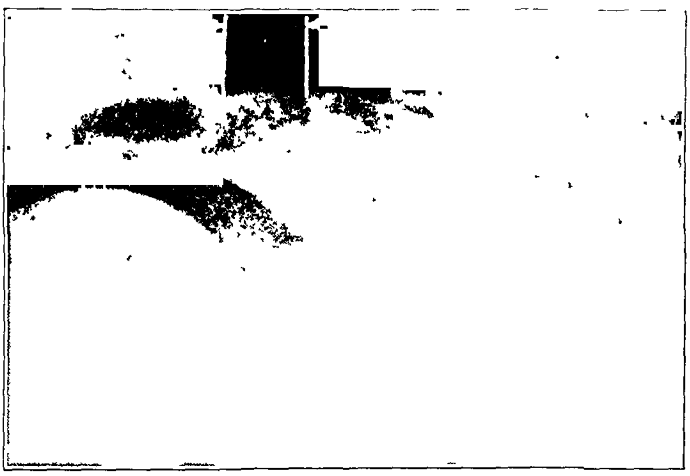

Fig. 3

Case 17. Roentgenogram of severe dislocation of right acromioclavicular joint, sustained in a motorcycle accident. Interposition of the capsular ligament is suspected, because the joint space was greatly increased on the affected side after reduction of the dislocation. This is the vertical type of joint.

These fifteen patients, who were seen early enough to be treated by conservative methods, wore the splint for six weeks and had two weeks of physical therapy before the first record of results was made. All, however, were examined from three to four weeks after the application of the splint by folding the shoulder strap medially on itself and determining the mobility of the acromial end of the clavicle. Three patients (Cases 5, 6, and 34) showed free floating of the outer end of the clavicle (ballottement), as well as pain, swelling, and tenderness over the joint. In all of these cases the deformity recurred at six weeks, when the splint was removed. Operations in Cases 5 and 6 revealed interposition of the capsular

FIG. 4

Case 16. Roentgenogram of severe dislocation of right acromioclavicular joint, sustained in fall over fence on dark battlefield. Correction has been obtained by author's splint. A false impression of overcorrection of the deformity may be obtained when, as in this case, the clavicle is displaced posterior to the acromion, but is actually farther from the coracoid process than on the opposite side. If treatment is undertaken early, the faulty position can be improved by manipulation under the shoulder strap.

ligaments and interference with satisfactory reduction of the dislocations, which were not evident in anteroposterior roentgenograms of the shoulder. If a larger experience confirms these early observations, the sign of the free floating end of the clavicle may indicate the cases in which conservative treatment should be abandoned early.

The results in these fifteen cases are in accord with those of other observers[17,51,93], whose reports show 10 to 20 per cent. of failures by newer conservative methods of treatment. Many surgeons are convinced that complete dislocations respond to non-operative methods of treatment in a high percentage of cases[1,26,92,99], while others, equally experienced, are rather pessimistic[19,32,45,62,83,85,97]. The periodic revival of the concept that strappings are adequate for all cases, if rigorously tended, is generally disregarded by surgeons who have observed the comforts of more effective, newer methods[1,23,37,47,82]. It should also be emphasized that many papers which present highly successful results with obviously inadequate methods of treatment deal only with sprains, subluxations, or incomplete dislocations of minor degree, such as the average football injury sustained in "blocking", and not with complete dislocations[26,47].

Three other patients (Cases 16, 17, and 18) were seen ten days after injury, in adhesive strappings, from which they were transferred to the writer's splints for six weeks of additional immobilization. At the end of treatment, varying degrees of subluxation were present in all cases, but the associated symptoms were neither severe nor disabling. All three patients returned to duty, apparently perfectly satisfied with the results obtained.

The following case report illustrates the successful result of conservative therapy:

CASE 1. This patient, while sitting in the front seat of a jeep, was thrown out after a head-on collision with another vehicle and struck his right shoulder on the pavement. The application of a Velpeau bandage in a local dispensary failed to hold the shoulder in a satisfactory position. Twenty-four hours later the dislocation was reduced and the shoulder was immobilized in the writer's splint (Figs. 1-A to 1-D), which was maintained unchanged for six weeks. At the end of this period, roentgenographic examination showed the correct anatomical position. There was slight induration about the acromioclavicular joint and slight crepitus was observed, but the patient had full range of motion and no symptoms were present after ten days of physical therapy. He returned to full duty, including calisthenics and sports, eight weeks after the injury.

SURGICAL METHODS

Among the various surgical methods for the treatment of complete dislocation of the acromioclavicular joint, the most important are arthrotomy and internal fixation, arthrodesis, coracoclavicular screw fixation, syndesmoplasty, ligamentopexy, and arthroplasty. One patient in this series was treated by open reduction and internal fixation with a transarticular wire (Case 32), one by the coracoclavicular screw (Case 33), two by skeletal traction (Cases 30 and 31), and nine by excision of the outer end of the clavicle (Table V).

TABLE V

SIGNIFICANT DATA IN NINE COMPLETE DISLOCATIONS OF THE ACROMIOCLAVICULAR JOINT TREATED BY EXCISION OF THE DISTAL END OF THE CLAVICLE

Case No.	Type of Joint	Primary Treatment	Result	Interval Before Surgery	Operative Findings	
					Coracoclavicular Ligaments	Joint
35	Overriding	Stimson's strapping	Poor	4 weeks	Stretched, but intact	Fibrous adhesions
36	Overriding	Watson-Jones's strapping	Poor	4 weeks	Trapezoid stretched and frayed	Interposed capsule and fibrous adhesions
37	Overriding	None	Poor	3 weeks	Intact	Interposed capsule and fibrous adhesions
38	Incongruent, overriding	None	Dislocation	12 months	Intact	Chronic synovitis or fibrous ankylosis
39	Incongruent, overriding	Adhesive brachioclavicular sling	Subluxation	11 months	Ossified	Extra-articular new bone
40	Incongruent, overriding	Arm sling	Subluxation	10 months	Ossified	Extra-articular new bone
41	Incongruent, overriding	Velpeau bandage	Subluxation	5 months	Intact	Interposed fibrous connective tissue
5*	Vertical	Author's splint	Subluxation	10 weeks	Intact	Interposed capsule and fibrous adhesions
6*	Incongruent, vertical	Author's splint	Subluxation	10 weeks	Intact	Interposed capsule and fibrous adhesions

* See Table II for additional details concerning these two cases.

Arthrotomy and Internal Fixation

Many surgeons[61,78,97] have reported good results, including correction of the deformity, following arthrotomy and internal fixation by silver wire[19,97], phosphobronze wire[58], steel wire[16,29,50], chromic catgut[33,76], screws[13], Parham bands, silk[13,63], and fascia[31], among other materials. Improvement in results has been reported by the use of extra-articular suture with arthrotomy in combination with arthroplasty, or by the use of periarticular[91] or coracoclavicular screws without arthrotomy[10,99].

Bloom and Phemister have reported good results following the use of transarticular Kirschner wires with arthrotomy, and Murray has used the same method without arthrotomy. The three authors report a total of twenty-seven cases. An extra-articular technique with Kirschner wire is also mentioned[81]. The writer observed one case (Case 32) six months after the operation, treated by another surgeon, in which the deformity was corrected satisfactorily by Phemister's technique.

The end results in all these operations depend, just as when non-surgical methods are used, on the healing of the ligaments and of the periarticular structures. These surgical measures should be instituted early; they are more likely to be unsuccessful in neglected or old dislocations. The theoretical advantage of arthrotomy is that more accurate fixation of the non-osseous parts of the joint can be achieved by reposition and suture under direct vision, but the reports suggest that the cosmetic results and symptomatic cures are approximately the same as those achieved by the writer and by others[47,93] who used improved conservative methods.

Arthrodesis

Before World War I, operations for suturing the acromioclavicular joint frequently resulted in ankylosis. Later, the articular cartilages were resected, to ensure bony fusion, which would correct deformity and relieve pain. Limitation of motion of the shoulder,

FIG 5-A

FIG 5-B

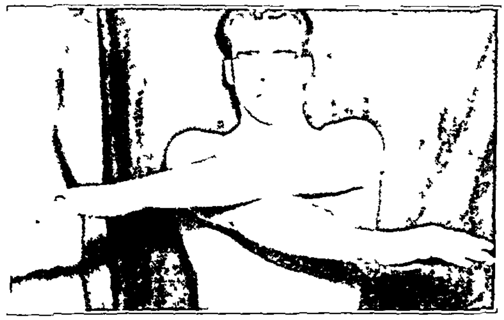

FIG 5-D

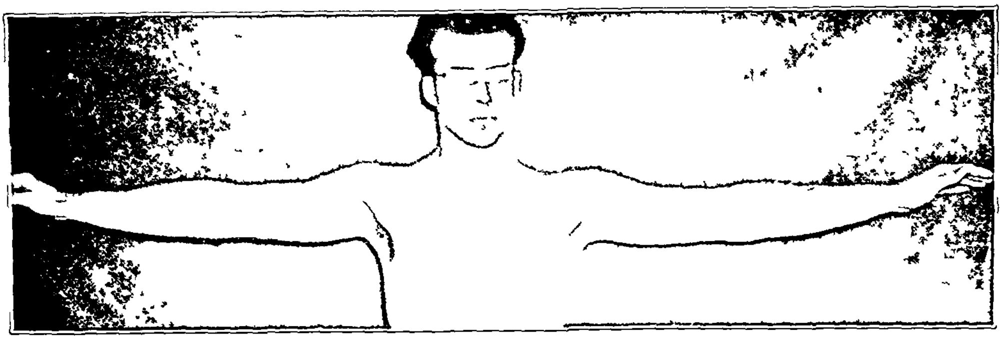

FIG 5-C

Fig 5-A Case 5 Complete dislocation of left acromioclavicular joint was sustained in a football game. Photograph taken ten days after excision of outer end of clavicle and just after removal of sutures from the incision, through which the coracoclavicular ligaments were also explored The affected shoulder is slightly lower than the intact shoulder as the scapula falls forward and lower on the thorax

Fig. 5-B Twenty-one days after operation, full elevation of arm is possible

Fig. 5-C Functional result fifteen days after operation; range of active abduction is 90 degrees.

Fig 5-D Functional result twenty-eight days after operation; painless crossing of elbows on the chest is seldom possible with any appreciable acromioclavicular separation.

particularly of abduction, was soon observed in such cases; and experimental observations on cadavera furnished the explanation, which is that the articulations of the clavicle, the scapula, and the humerus must function independently for elevation of the arm. Arthrodesis of the acromioclavicular joint is mentioned repeatedly in the literature up to the present time[14] as a solution for the problem of complete dislocation It is not, however, an acceptable procedure. As Inman and his associates have pointed out, the clavicle rotates on its long axis and must not be fixed, if comfortable elevation of the arm beyond 90 degrees is expected to continue.

Coracoclavicular Screw Fixation

Bosworth in 1941 used a lag screw, inserted through the clavicle into the coracoid process, to fix the position of the dislocation; he employed the method in four cases. Experienced clinicians[94,99], who currently advocate the method, teach that the screw must not be turned so tightly as to prevent "normal" motion of the clavicle, and they also advocate active exercises after operation.

The writer's experience is that normal motion of the clavicle is impossible with this method of fixation, since the clavicle rotates on its long axis with abduction The effect on the shoulder as a whole is the same as the effect of fusion of the acromioclavicular joint[13,64]; the fixation of the clavicle to the scapula limits abduction of the arm and causes pain, if motion is attempted beyond 90 degrees[48].

Watson-Jones, who recommends removal of the screw after four to six weeks in most cases, reports that results by this method are better than after conservative methods, by

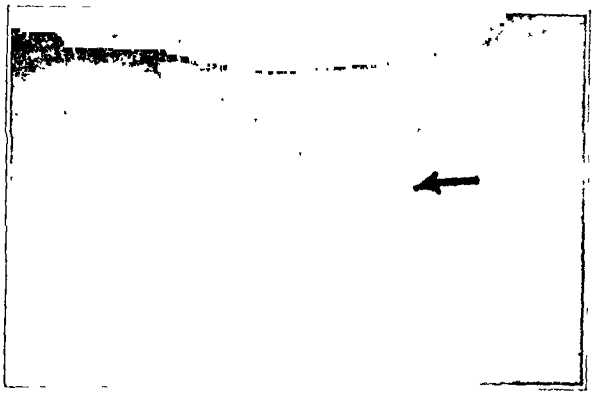

FIG. 6

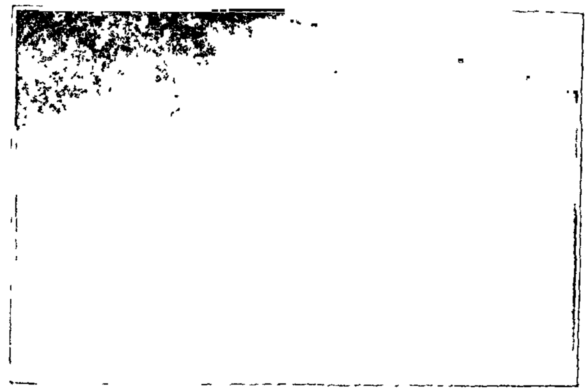

FIG. 7

Fig. 6: Case 7. Roentgenogram of avulsion fracture of medial aspect of right coracoid process, sustained in jeep accident. After overcorrection of deformity in author's splint for six weeks, this patient had a perfect cosmetic and functional result.

Fig. 7: Case 9. Roentgenogram of dislocation of right acromioclavicular process with minute fracture of distal end of inferior margin of clavicle, seven weeks after injury was sustained by tank striking tree in combat. Note calcification of inferior capsular ligament. This patient complained of pain and had limitation of abduction of the arm beyond 90 degrees. The (intact) joint is partly underriding at the inferior margin, because the articular clavicular surface is concave and the acromial surface is convex.

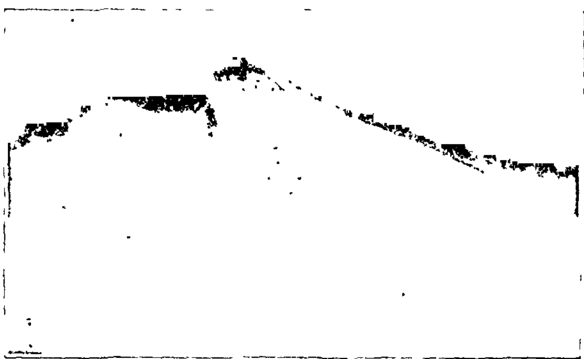

FIG. 8

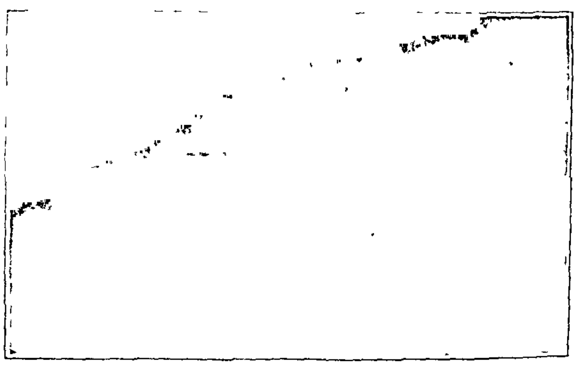

FIG. 9

Fig 8: Case 19. Roentgenogram of dislocation of left acromioclavicular joint, seven weeks after fall from motorcycle. Note calcification under clavicle. Deposits had been evident three and one-half weeks after the accident, but did not show up clearly enough for reproduction.

Fig. 9: Case 4. Dislocation of right acromioclavicular joint, eight weeks after injury had been sustained in a motorcycle accident. Ossification of the coracoclavicular ligaments and calcification of the meniscus, with a chip fracture of the acromion, are demonstrated by soft-tissue roentgenographic technique. The joint line is nearly vertical.

which he presumably means adhesive strappings. The end results of enough documented cases are, however, not yet available to permit final statements. The writer observed one instance (Case 33) in which the screw became loose four weeks after insertion, due to bone resorption, and the application of another splint was necessary.

Treatment by the coracoclavicular screw is limited to fresh injuries, and it is doubtful whether patients who do not respond to non-surgical methods, because of the interposition of soft parts, will be aided by it. The same objections apply to it as apply to all operative methods which do not include arthrotomy.

Syndesmoplasty

Direct surgical repair of the conoid and trapezoid ligaments is probably impossible because of their inaccessibility after even the best exposure[77]; but suture has been accomplished by indirect methods, including repair of the acromioclavicular joint. Approximation of the ligaments was obtained when the clavicle was bound to the coracoid process with heavy silk[11,17,18,24,59,89] or with wire[13,19]. The periarticular ligaments have also been repaired by transfer of fascia or ligaments at the site of the lesion[13,17,95]. Conclusive information as to the final results of syndesmoplasty has not yet been recorded.

Ligamentopexy

Reconstruction of the conoid and trapezoid ligaments[11,42,45,62,85] or of the coraco-clavicular and acromioclavicular ligaments[2,12,27,33,78,81] with an isograft of fascia lata is a surgical feat which, until recently, was considered an effective solution for old dislocations with extreme deformities. Henry protected the new ligament by fastening the clavicle in position with an extra-articular loop of silver wire. Bunnell's method is more difficult[11] than Henry's, but is more effective because the capsule of the acromioclavicular joint is also reinforced with fascia.

Equally experienced surgeons both recommend[9,60,66,86] and oppose[57,99] such operations. The grafts of fascia lata which form the new ligaments are reported to stretch, with subsequent recurrence of the deformity, and the disability is aggravated by postoperative stiffness of the shoulder. The fascia or old ligaments almost invariably calcify, and the resulting synosteosis limits abduction[6,54].

Skeletal Traction

Skeletal traction has been used for bedfast patients, suffering from severe injuries of the ribs and chest and other complications. It is capable of providing and maintaining the

FIG. 10

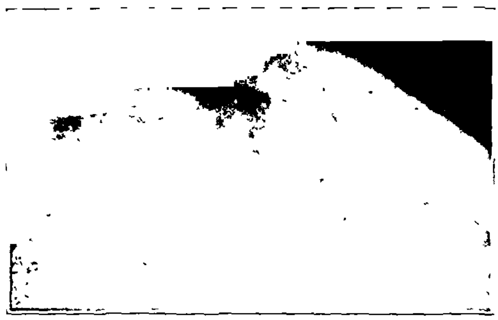

FIG. 11

Fig. 10: Case 27. Dislocation of left acromioclavicular joint, sustained in fall from moving tank. Roentgenogram shows calcification of capsular ligament four months later. The patient had mild symptoms of traumatic arthritis at this time. This is an extreme example of the overriding type of joint, the articular surfaces being nearly horizontal.

Fig. 11: Case 26. Dislocation of right acromioclavicular joint, showing coracoclavicular synosteosis, ten weeks after automobile accident caused by artillery blast. The patient had slight pain and limitation of abduction at this time. Because of other injuries, he was evacuated to the Zone of the Interior for treatment.

FIG. 12

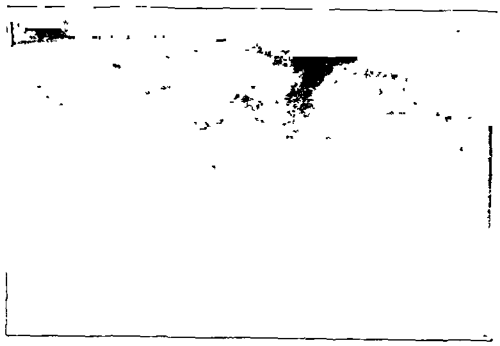

FIG. 13

Fig. 12: Case 24. Roentgenogram of dislocation of left acromioclavicular joint, incurred when jeep rolled down an embankment under enemy fire, shows coracoclavicular synosteosis nine months later. The patient had moderate pain and was unable to abduct the arm beyond 80 degrees. (Illustration has been reversed.)

Fig. 13: Case 39. Healed dislocation of acromioclavicular joint, sustained when patient was kicked squarely on point of shoulder in a football game. Roentgenogram, ten months after accident, shows loose osteocartilaginous bodies in joint and ossification of insertions of trapezoid ligament. The patient experienced annoying crepitations, had pain when doing heavy work, and had 30 degrees of limitation of abduction.

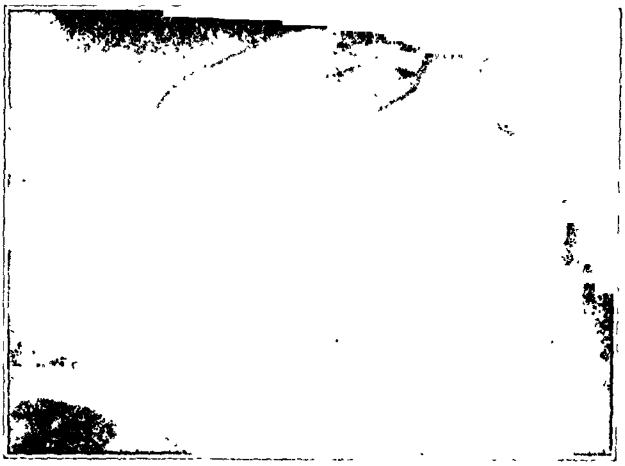

FIG. 14-A

FIG. 14-B

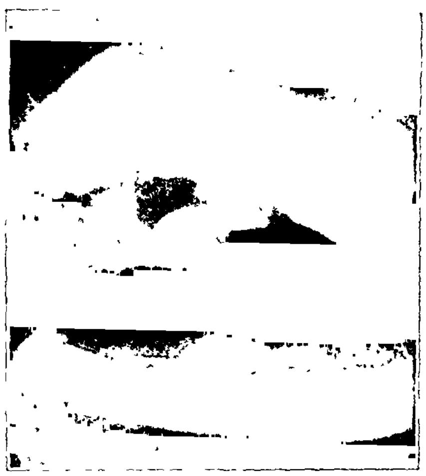

FIG. 14-C

Fig. 14-A: Case 40. Old dislocation of left acromioclavicular joint with linear fracture at junction of middle and outer thirds of clavicle, produced by direct blow over shoulder in jeep accident in combat. Note synosteosis at site of fracture, ten months after accident. Immediately after the injury, ecchymosis and marked swelling were present over the lateral aspect of the neck and the dorsum of the shoulder.

Fig. 14-B: Roentgenogram after excision of outer third of clavicle. The patient had complete relief of symptoms and returned to full duty in twelve weeks.

Fig. 14-C: Superior and inferior aspects of excised clavicle. Note new-bone formation on antero-inferior attachments of trapezoid ligament.

anatomical position continuously for four weeks, as shown in anteroposterior and oblique roentgenograms Traction is obtained by the use of small threaded pins,— two inserted in the outer third of the clavicle and one inserted into the coracoid process and tied together in a triangle with elastics. Rubber bands serve, in effect, as a second, external set of ligaments, and maintain reduction by continuous skeletal traction. The patient, to relieve the tension, involuntarily elevates the shoulder on the affected side and thus actively aids in maintaining the reduction.

The method can be used only on fresh cases. All the well-known disadvantages of external skeletal fixation obtain, and the use of the technique should be limited to unusual circumstances. This is not a method applicable to military or industrial practice.

Excision of the Outer End of the Clavicle

Morestin, late in the Nineteenth Century, resected just enough of the outer end of the clavicle in two cases of acromioclavicular separation to remove the subcutaneous projection of the bone, and similar operations have been done for osteomyelitis and for tumors[28]. Surgical excision of the outer end of the clavicle has frequently been done for arthritis and other conditions[67,99]. These operations, as well as parallel observations on individuals with partial[88] or complete absence of the clavicle[72], led to the conclusion that absence of the clavicle is better than acromioclavicular ankylosis, and that there is little postoperative disability, other than possibly slight impairment of the muscle coordination needed for forceful forward thrusts of the arm or for acrobatics[46].

Mumford and Gurd almost simultaneously revived interest in this operation, both for fresh cases and for old dislocations of the acromioclavicular joint. Rowe added suture of the cut end of the clavicle to the coracoid process with nylon, but most surgeons do not regard this as a necessary part of the operation. The writer resects from six to eight centimeters of the clavicle, so that the stump is excluded from interference with the motions of the scapulohumeral joint.

This method attained wide favor in the Armed Forces, and nine cases in this series were so treated (Table V) after conservative methods had failed. The cosmetic result in all instances was excellent (Figs. 5-B and 5-D), as the contour of the dorsum of the shoulder was maintained by the acromion; but neither the function nor the appearance of the shoulder should be described as "normal". A patient in whom the outer end of the clavicle has been excised clearly demonstrates that the clavicle acts as a kind of yardarm, which prevents the shoulder from falling anteriorly and inferiorly on the chest wall (Fig. 5-A), and that this is probably its most important function in man. In young men, the musculature of the shoulder girdle compensates for the stability which is lost with the absence of the clavicle, but all of the nine patients admit having earlier fatigue or slight weakness in the shoulder on prolonged vigorous exercise, as compared with the intact opposite side. Disability and pain from the acromioclavicular dislocation, however, were relieved completely within a few weeks after the operation.

The two case histories which follow illustrate the indications and results of this surgical method.

CASE 5. A football player was struck sharply over the dorsum of the shoulder by an opponent, who blocked him out of a line play. A Velpeau bandage was applied at an aid station, and was replaced two days later by the splint devised by the writer. Roentgenograms showed excellent reduction, but with slight widening of the acromioclavicular joint as compared with the joint on the opposite, intact side. Four weeks after the injury, the distal end of the clavicle was abnormally mobile and apparently floating free. At six weeks, the splint was removed and daily exercises at the shoulder wheel were begun. At eight weeks there was 30 degrees of limitation of elevation of the arm, and pain and crepitus were experienced when the patient was at the shoulder wheel. The distal end of the clavicle rose out of the joint when the arms were folded across the chest. Ten weeks after the injury, the soldier was examined in the outpatient clinic and it was concluded that his complaints were justified and that further treatment was indicated. The distal end of the clavicle was therefore excised. Exercises were begun before the sutures were removed. Three weeks after operation there was no deformity, no limitation of motion, no crepitus, and no other symptoms or disability. The patient cheerfully returned to full duty. This case represents one of the instances in which the ruptured acromioclavicular joint fails to heal under ideal conditions.

CASE 40. This patient sustained a fracture of the left clavicle, with separation of the acromioclavicular joint, in a jeep accident in France. The fracture healed uneventfully and in good position, and the soldier returned to combat. Nine and one-half months after the accident, he reported that pain had begun in the left shoulder and had become increasingly severe. It was aggravated by exercise in games and calisthenics. Physical examination showed that the clavicle on the injured side was more prominent than on the normal side; the acromioclavicular joint was painful to palpation, but was not abnormally mobile. There was 30 degrees of limitation of abduction of the arm. Roentgenograms showed a well-healed fracture at the junction of the middle and outer thirds of the clavicle, with synosteosis between the fracture site and the coracoid process and ossification of the conoid and trapezoid ligaments.

At operation, a mass of bone and scar tissue was found throughout the insertion of the subclavius muscle and the region of the coracoclavicular ligaments. A column of bone was palpable between the site of the old fracture and the coracoid process. The distal third of the clavicle and the ossified coracoclavicular ligaments and scar were removed *en masse*, with a minimum of dissection. Physical therapy was begun as soon as the sutures had been removed. At the end of three weeks the patient could lift heavy weights and had full range of motion; he was therefore discharged to full duty.

ASSOCIATED FRACTURES

As already noted, eleven patients in this series presented, in addition to complete dislocation of the acromioclavicular joint, twelve associated fractures, distributed as follows:

Clavicle (*Eight Fractures*): One was a transverse fracture at the junction of the middle and outer thirds of the shaft (Case 40); four were subchondral compression fractures (Cases 5, 35, 36, and 41); one was a chip fracture of the acromial end of the inferior margin, in a partially undergliding joint (Case 9, Fig. 7); and two were avulsion fractures of the trapezoid ridge (Cases 8 and 16).

Acromion Process (*Two Fractures*): One was a chip fracture (Case 4, Fig. 9) and one a fissure fracture (Case 34).

Coracoid Process (*Two Avulsion Fractures,* Cases 7 and 34): The fracture in Case 34 was in addition to a subchondral compression fracture of the clavicle.

As is true of similar traumatic lesions in dislocations in other areas of the body, the ligament presumably suffered less damage when its bony insertion was avulsed. The presence of avulsion fractures of the coracoid process did not influence healing adversely, and conservative therapy gave good results in both cases; ossification of the coracoclavicular ligaments occurred in all. The same was true of the single avulsion fracture of the inferior surface of the clavicle. Painful abduction was present in three of the five cases in which articular surfaces were involved in the injury, and painful joints persisted for a time in all; but these symptoms eventually disappeared in all but one case (Case 8), in which excision of the outer third of the clavicle was eventually necessary.

Primary excision of the joint is probably not justified in dislocations associated with fractures in military surgery, until a period of duty establishes disability, as the following case shows.

CASE 34. This patient, an engineer, was struck on the left shoulder by a falling beam as he was working with a crane. Roentgenographic examination, one hour later, showed a linear fracture of the acromion process without displacement, avulsion of the coracoid process, and acromioclavicular separation.

Because of the swelling and ecchymosis over the dorsum of the shoulder, the plaster-of-Paris abduction splint of Key and Conwell was considered more practical than the Legg-Girard splint, which requires the pressure of a shoulder strap. (The acromioclavicular separation, however, is only partially reduced by this method, because the distal end of the clavicle is displaced slightly posteriorly, and the distance between the clavicle and the acromion process is undesirably increased.)

At the end of two weeks, the dorsal section of the cast was removed, and massage and biceps-setting exercises were ordered. At six weeks, the remainder of the cast was removed and limited exercises were undertaken. At eight weeks, the patient began to use the shoulder wheel. Roentgenographic examination at this time showed union of the coracoid process to the scapula and complete healing of the fracture of the acromion process. When the patient returned to duty, twelve weeks after the accident, he had a slight subluxation, but was free from symptoms.

COMPLICATIONS AND SEQUELAE

Pain and limitation of motion may develop early or late and in any type of case, regardless of whether it was untreated, poorly treated, or well treated. The management depends upon the etiology.

Arthritis

Osteo-arthritic changes in the articular surfaces of the acromioclavicular joint, calcifications in the capsular ligament, and loose osteocartilaginous bodies were found on roentgenographic examination in twelve cases in this series (Figs. 9, 10, and 13). Five were treated by excision of the distal end of the clavicle, and had complete relief of symptoms within three weeks after operation.

Atrophy or rarefaction of the acromial end of the clavicle was apparent in the roentgenograms in almost all severe or old cases. When immobilization was discontinued, if the dislocation remained reduced and normal function had been resumed, the density of the bone gradually returned to normal.

In two cases in this series (Cases 35 and 36), so-called avascular necrosis or osteochondritis[89] was observed. In both cases, subchondral fractures were found at open operation. Gross examination and roentgenographic examination of the excised specimens showed sclerosis of old bone, irregular areas of resorption, and new subperiosteal bone formation, typical of the process of healing of crushed spongiosa. Avascular necrosis is not frequent, but should be expected in severe cases, as demonstrated by the roentgenograms, whether or not reduction has been accomplished.

All the changes described, although they are regarded as evidence of traumatic arthritis by many observers[13,55,60,67,99], do not necessarily give rise to symptoms. Although they were present in roentgenographic examinations in twelve cases, only seven of the patients had genuine pain.

Calcification and Ossification of Soft Parts

Calcified structures between the coracoid process and the clavicle have frequently been described and various interpretations have been placed upon them, depending upon their location. They have appeared in ossifying hematoma[49], in a bursa between the conoid and trapezoid ligaments[56], under the torn periosteum[99], and in the substance of the torn ligaments[6,26,38,54,84,97]. Šváb demonstrated that the new bone may arise in endochondral ossification, presumably of primitive connective-tissue cells in the substance of the ligament. Wakeley regards the phenomenon as a hopeful sign of the reuniting of the torn ligaments. Ligamentopexy invariably results in ossification of the ligaments, and transplanted fascia lata in this region has the same fate[60].

Calcification of the conoid and trapezoid ligaments was demonstrated roentgenographically in eighteen of the cases in this series (Figs. 8 to 14-C). The deposits first appeared within three or four weeks after the injury, and increased in density and extent through several months of healing. The final size of the deposit varied between a fleck, which could be demonstrated only by oblique roentgenograms, by soft-tissue technique, and massive ossification of the coracoclavicular ligaments and synosteosis of the clavicle and scapula. Gross and roentgenographic examination of the new bone in excised specimens showed that it appeared in some cases as an outgrowth from the periosteum of the clavicle or the coracoid process, and in some it appeared as an unattached body.

The complaints and physical examinations in these cases showed that, up to the point of actual fusion of the clavicle and scapula, the deposits were of no clinical significance. When the synosteosis was nearly complete (Case 24), the range of motion of the coracoclavicular syndesmosis was diminished, and the effect on function was the same as if ankylosis of the acromioclavicular joint had occurred. In the case mentioned, abduction beyond 90 degrees was painful and limited, although the degree of subluxation was only moderate. Both the symptoms and the deformity were relieved by excision of the outer end of the clavicle.

Synovitis and Joint Adhesions

When synovitis and adhesions are present in acromioclavicular dislocation, the patients complain of vague pains and uncomfortable crepitations in the absence of roentgenographic changes in the bone or joint, sometimes associated with swelling over the acromioclavicular articulation. This occurs whether or not treatment of the deformity has been successful. The patients also complain of instability with extreme motions of the shoulder, although this usually disappears over a period of years. Köstler emphasizes the dislocation of the meniscus as a factor in such cases.

One patient in this series (Case 6) requested further treatment a year after treatment of a complete dislocation, on the ground that, because of the symptoms mentioned, he could not perform his duties as a stevedore. Excision of the outer end of the clavicle showed the joint cavity to be obliterated by intra-articular fibrous connective tissue, calcified capsular ligament, and torn meniscus, which Köstler has emphasized as the inciting factor in such cases.

SUMMARY AND CONCLUSIONS

1. Complete dislocation of the acromioclavicular joint may occur with, or more often without, gross rupture of the coracoclavicular ligaments. The normal excursion of the conoid and trapezoid ligaments permits dislocation when the joint alone is involved.

2. Calcification and ossification, observed with the aid of soft-tissue roentgenographic techniques, were found in the region of the conoid and trapezoid ligaments in approximately half of this series of forty-one cases. This phenomenon may be interpreted as a part of the process of healing of the ligaments.

3. The possible anatomical variations from the supposed normal joint structure may determine the success or failure of conservative treatment and the incidence of sequelae.

4. Improved methods of conservative treatment may be expected to correct the deformity and relieve symptoms in approximately 80 per cent. of the cases of complete dislocation of the acromioclavicular joint. In the remaining 20 per cent., deformity, pain, or limitation of motion may indicate the need for additional treatment by surgical measures.

5. A modification of the splints devised by Dillehunt, Howard, Shaar, and Legg is capable of overcorrection of the deformity, which is the key to success with conservative measures.

6. The chief obstacle to effective conservative treatment is interposition of soft parts,—such as meniscus, frayed capsular ligament, and flakes of articular cartilage between the joint surfaces.

7. Excision of the outer end of the clavicle, used successfully in nine cases in this series, is apparently the most uniformly successful method of treatment for both recent and old *complicated* acromioclavicular dislocations.

8. Two observations of possible diagnostic and prognostic importance were noted in the course of the study, although the limited number of cases does not permit positive statements concerning them at this time: (a) An increase in the width of the joint space on the injured side, demonstrated roentgenographically, indicates posterior displacement of the outer end of the clavicle, even when the acromion process and the clavicle are correctly aligned. (b) Palpable posterior displacement and abnormal mobility of the outer end of the clavicle, after three weeks of healing, indicate the probable failure of conservative methods and the recurrence of the dislocation.

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OBSTETRICAL DISLOCATION OF THE HIP ASSOCIATED WITH FRACTURE OF THE FEMUR

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Traumatic dislocation of the femur is rare, because the ligaments which reinforce the capsule are very strong. In cases of excessive trauma—as from energetic traction—epiphysiolysis or fracture of the femoral diaphysis may be produced, but not dislocation. It is for this reason that treatises on fractures rarely mention dislocation of the femur of obstetrical origin.

The two cases presented here are cases of real fracture-dislocation of the hip, caused by forcible manoeuvres during birth. Breech deliveries were performed in each case; the thigh was subjected to strong traction with rotation and extreme abduction during the course of the delivery.

This type of fracture-dislocation may be differentiated from the more usual type of congenital dislocation upon the basis of roentgenographic findings.

The clinical picture of the obstetrical fracture-dislocation is characteristic: After a difficult delivery, an apparent disproportion in the length of the infant's limbs will be noted. In addition, there is intense pain upon motion of the injured limb. After two or three days a swelling of the inguinal region, the thigh, and the gluteal region may be noted. There is a brawny induration, and a slight elevation of temperature of the skin. The limb is held in a characteristic position of external rotation and slight flexion.

Because of the pain, the child does not gain weight or sleep calmly. He is startled easily and has a poor appetite. He cries violently when the mother attempts to change his clothes. There is shortening of the thigh, and the greater trochanter lies above the Nélaton-Roser line.

The prognosis is favorable when treatment is undertaken within the first fifteen days after birth. In the cases presented here, the patients have been completely cured. No case of luxation with untreated fracture has been observed. The treatment consists of reduction and proper immobilization. In the reduction, the Lorenz procedure, employed in the treatment of congenital dislocation, is utilized. Under ether anaesthesia, the opposite hip

Fig. 1-A

Fig. 1-B

Fig. 1-A: Roentgenogram taken two days after birth, on October 18, 1943.
Fig. 1-B: December 29, 1943.

FIG. 1-C
Four months after reduction.

FIG. 1-D
April 11, 1944.

FIG 1-E
April 11, 1944.

FIG 1-F
July 18, 1944

is fixed, while the operator flexes the injured thigh upon the abdomen. With both hip and knee flexed, the extremity is externally rotated. Usually a snap, produced by the head dropping into the acetabulum, is felt during the course of this manoeuvre The reduction is performed with roentgenographic control. If satisfactory, the limb is placed in a position of 135 degrees of flexion, 40 degrees of abduction, and slight internal rotation.

FIG 1-G
Final result, on January 9, 1946.

Castex is preferred to the ordinary plaster-of-Paris spica, because it is lighter and waterproof. The plaster is left in place for a period of forty-five days After removal of the plaster, all other forms of treatment—such as massage and exercise—are found to be unnecessary. The results of such treatment are good, and are illustrated in the following cases.

Fig. 2-A

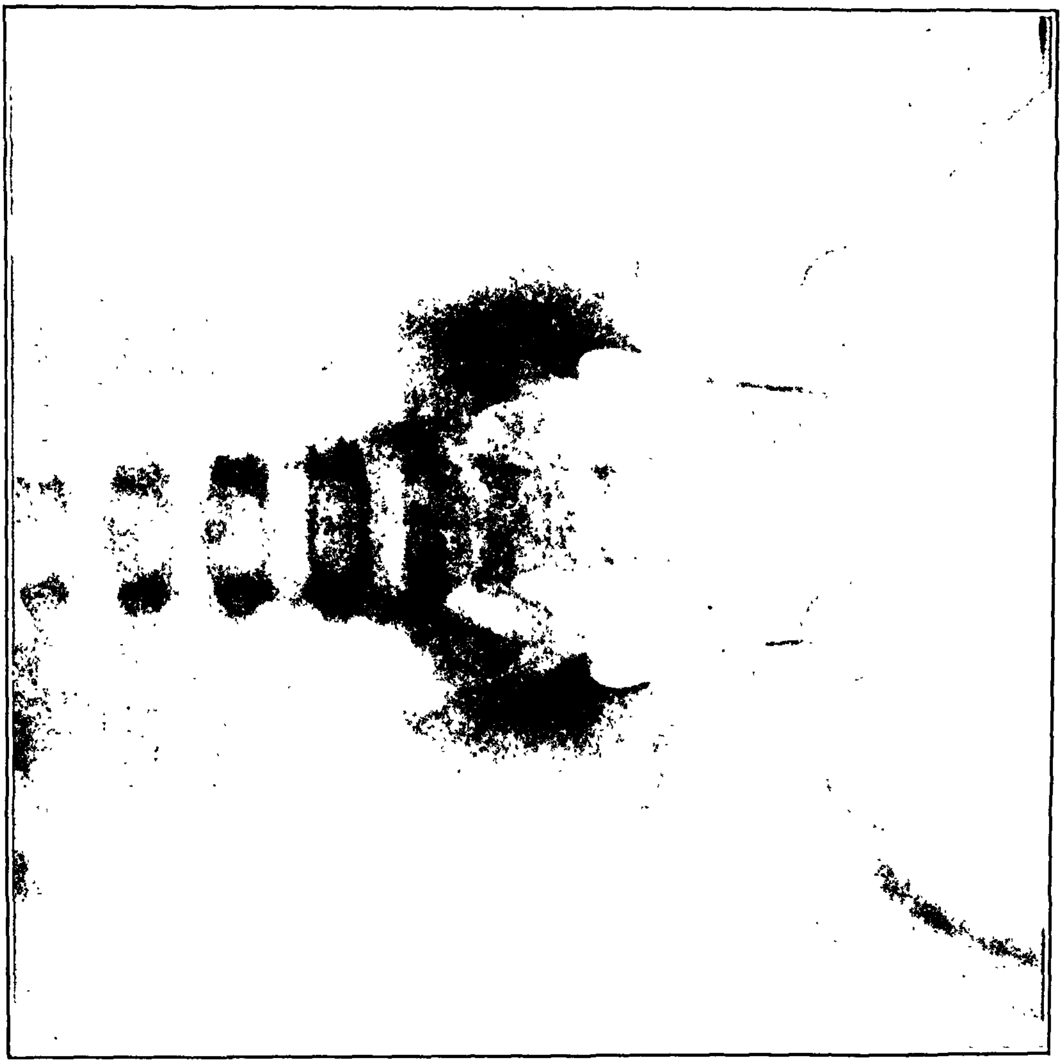

Fig. 2-B

Fig. 2-A: Roentgenogram taken on August 25, 1944, fifteen days after birth, before treatment was initiated.
Fig. 2-B: Final result on January 3, 1946, seventeen months after reduction.

CASE REPORTS

CASE 1. S. C., a girl, was born on October 16, 1943, after a difficult delivery, during which traction was exerted upon the left lower extremity. On the day after delivery, the parents noted a swelling of the thigh, with a slight shortening of the left limb. All movements were extremely painful, and several times the child awoke and cried out. Two days after birth, roentgenograms (Fig. 1-A) revealed a supra-acetabular subluxation. This was associated with several loose bone flakes in the cortex of the greater trochanter. There was slight elevation of the pelvis on the affected side, but the acetabulum had the same appearance as that on the normal side.

On November 3, 1943, reduction was accomplished, according to the technique described. After the reduction a plaster was applied; this was removed at the end of forty-five days. At that time the loose trochanteric fragment was united to the lateral surface of the trochanter. The dislocation had been overcome, but a slight varus deformity of the femoral neck was present. There was marked periosteal thickening of the femoral diaphysis.

In the roentgenogram taken on February 28, 1944 (Fig. 1-C), there appeared to be a slight increase in the varus position of the neck, suggestive of the beak of a parrot. The diaphysis was thicker. In contrast to the findings in congenital dislocation of the hip, the epiphyseal nucleus was visible on the affected side, but not on the normal side. Roentgenograms taken five months after injury (Figs. 1-D and 1-E) showed complete recovery. The capital epiphyses could be seen on both sides. The slight varus position of the neck and the slight thickening of the shaft were still present. Roentgenograms (Fig. 1-F), taken eight months after treatment, revealed the persistence of varus of the neck.

There was no shortening of the limb. At fourteen months of age the patient began to walk. At the present age of two years and three months, the gait is normal and there is no atrophy of the thigh muscles. The final result is shown in Figure 1-G.

CASE 2. H. C. was born on August 10, 1944, after a hard delivery, during which it was necessary to exert energetic traction on the right lower extremity. A mild shortening of the limb, pain on motion, and prominence of the greater trochanter were noted. Two days later oedema of the thigh was observed. A roentgenogram taken fifteen days after birth (Fig. 2-A) showed the typical fracture-dislocation, with increased distance from the femur to the pelvis and subperiosteal new-bone formation. Treatment was instituted in the usual manner. Upon removal of the spica at the end of forty-five days, the condition of the limb had improved. A roentgenogram taken at the end of four months showed complete healing of the fracture. The "parrot-beak" deformity of the neck was noted. On the right side the epiphyseal nucleus was more noticeable than on the healthy side. The affected femoral diaphysis was thickened.

The baby walked at the age of fifteen months, and his development has been completely normal. The roentgenographic findings seventeen months after reduction of the fracture are shown in Figure 2-B.

Two similar cases are at present under treatment, and it is believed that the end results will be as favorable as in the cases reported here.

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PANNER'S METATARSAL DISEASE: A CONDITION OF ASEPTIC NECROSIS SIMULATING MARCH FRACTURE

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Subperiosteal stratification of the distal shaft of a central metatarsal bone is generall; regarded as roentgenographic evidence of a march fracture when it first appears, in th absence of distinct recent trauma, in a young infantry recruit who suffers with a painfu foot[4]. A similar subperiosteal stratification may be associated with a varying degree o aseptic necrosis of the adult metatarsal head; Watson-Jones has pointed out the resem blance of the latter condition to march fracture. Although the name of Panner is asso ciated with this second condition, Köhler had previously described the thickening of th distal diaphysis[5]; Freiberg's illustrations also show thickening of the distal diaphysis, al though this feature was not specifically discussed. The voluminous current Americai literature on march fracture makes little or no mention of the condition. At an infantr; replacement center where several hundred march fractures were seen annually[3,6], the rar occurrence of Panner's disease occasionally caused difficulty in proper diagnosis; this wa: particularly true in that phase in which the subperiosteal stratification was the predomi nant roentgenographic feature. Usually the process is somewhat advanced when first seen in the following case, roentgenographic studies were made early in the course of the diseas and its entire cycle is presented roentgenographically.

FIG. 1

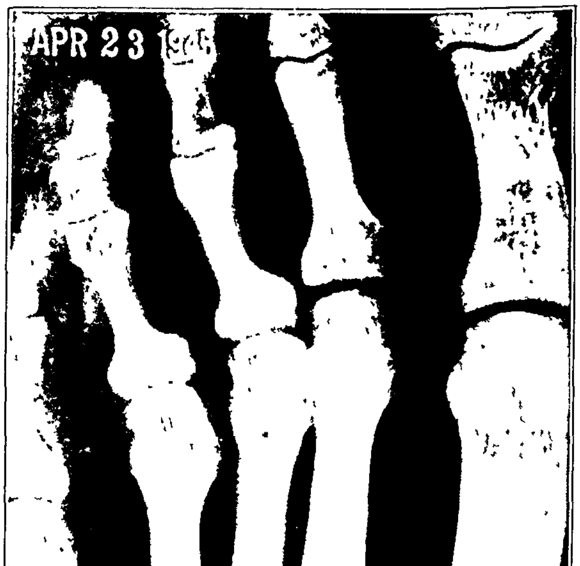

FIG. 2

Fig. 1: February 27, 1945. Left metatarsal area of an infantry recruit, aged twenty-five, who was undergoing strenuous training. Roentgenographic findings do not confirm the clinical impression of march fracture.

Fig. 2: April 23, 1945. Subperiosteal stratification, suggestive of an early march fracture, is seen on the third metatarsal shaft distally. Suggestive cystic changes are present in the metatarsal head.

CASE REPORT

In February 1945, one month after induction, an infantry recruit, twenty-five years of age, first complained of pain in the left foot following strenuous training No known trauma had occurred recently. There was a history of previous mild temporary disability, lasting for a few days, in the summer of 1944,

Fig 3

Fig 4

Fig 3 May 1, 1945 Note the similarity to march fracture of the third metatarsal
Fig 4. July 13, 1945 Definite cystic changes are now evident in the third metatarsal head

Fig 5

Fig 6

Fig 5 September 28, 1945 Oblique views, showing further progress of the process
Fig 6 November 13, 1945 Most of the third metatarsal head shows a cystic change

FIG. 7

December 5, 1945. Oblique view, showing the articular cartilage and subchondral bone, which have become separated from the remainder of the head and have collapsed into the cystic area to produce further deformity in outline of the metatarsal head.

after a wedge dropped on his left foot; no discomfort had occurred in the interim. On February 27, 1945, the attending medical officer ordered a roentgenogram (Fig. 1), which did not confirm the clinical diagnosis of march fracture. Subsequent roentgenograms (Figs. 2 and 3) appeared somewhat compatible with the clinical diagnosis of march fracture of the left third metatarsal. The institution of routine treatment for march fracture at this time, with metal reinforcement of the sole of the shoe, did not relieve the symptoms.

Because of the persistence of pain and limitation of motion in the left third metatarsophalangeal joint, the patient was referred to the consultant on arthritis, and later to the orthopaedic consultant, at the Regional Hospital. At this time, roentgenograms showed the typical picture of Panner's disease. Clinical examination of the feet was not remarkable, except for the presence of slight local swelling on the dorsum of the distal left metatarsal area with slight limitation of motion and pain at the left third metatarsophalangeal joint. The blood chemistry, including determinations of serum calcium, phosphorus, and phosphatase, was within normal limits, as were the sedimentation rate, routine blood studies, and urinalysis. Only limitation of activities afforded symptomatic relief. The general physical condition of the patient was excellent. When last seen, in December 1945, local examination disclosed moderate thickening about the left third metatarsophalangeal joint and pain on extremes of motion at this joint, with slight restriction of motion.

DISCUSSION

The cystic changes in the metatarsal head may not always be so marked as in the present case. The differentiation of Panner's disease from march fracture is essential from both prognostic and therapeutic viewpoints. A certain rigidity and mild pain persist in the affected metatarsophalangeal joint as a result of aseptic necrosis of the metatarsal head; patients with this condition do not respond to the ambulatory type of treatment which has proved satisfactory in most march fractures.

The occurrence of aseptic necrosis in the adult metatarsal head is less frequent than in the juvenile case, and it is not so generally recognized. Panner was not aware of the origin of the condition in an adult, and expressed the opinion that it began in childhood and progressed without symptoms. In the usual adult case, early roentgenograms have not been taken and, since the same condition was known in the juvenile, it is not difficult to understand the basis for Panner's conclusions. Gaitskell reported one case in which roentgenographic changes first occurred in adult life; the same is true in the present case.

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THE SUPRACONDYLOID PROCESS OF THE HUMERUS

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The presence of an anomalous bony spur on the medial aspect of the lower third of the humerus in approximately 1 per cent. of people of European ancestry has long been known to anatomists, anthropologists, and zoologists. However, its occurrence with a well-defined clinical syndrome has received very little attention in the medical literature of the English-speaking countries. The present article reports three cases encountered at an Army General Hospital, with a review of the anatomy and pathological findings discussed in the literature.

ANATOMY

This bony spur (variously named the supracondylar, epicondylic, or supra-epitrochlear process by different authors) occurs as a beaklike process, which arises from five to seven centimeters above the medial epicondyle of the humerus and extends obliquely downward and forward in a medial direction. The apex of the process is roughened and, in some cases, joined to the medial epicondyle by a band of fibrous tissue[2,9,10,11].

Through the foramen thus formed by the supracondyloid process and its ligamentous band, the median nerve usually passes. Frequently it is accompanied by the brachial artery or one of its branches[2], and by the radial or ulnar artery (Fig. 1). The process may afford insertion to a persistent lower part of the coracobrachialis[9]. Usually the pronator teres has an anomalous origin from the process, when present, as well as from the fibrous band [6,9], and overlies the median nerve and brachial artery at this point.

The supracondyloid process and its ligamentous band constitute the homologue in a rudimentary form of a bony canal, present in many animals. McGregor states: "An entepicondylar (supracondyloid) foramen is present in many extinct and living reptiles and in many mammals,—especially the mammalian orders which are archaic and primitive. Most marsupials have it, and it is present in many carnivores,—for example, the cat. Among Primates it is found in most lemurs, tarsies, and in many, but not all, American monkeys. Old-World monkeys do not have it, but among anthropoid apes it has been found occasionally in the orangutan and gorilla."

In this connection, Dwight reported a case of a bony supracondyloid foramen, found in the dissection of the body of a middle-aged female. A bony supracondyloid foramen has been reported by Cunningham[1] in a full-term stillborn infant.

INCIDENCE AND SYMPTOMS

For a number of years anthropologists have looked for and recorded the incidence of the supracondyloid process among primitive peoples and racial groups[5]. In the State of Mississippi, Terry[14] reported finding a supracondyloid process in 6 of 515 whites, but only once in 1,000 negroes. From these and from subsequent studies, he concluded that the supracondyloid variation appeared markedly among people of European stock and was probably indicative of fundamental differences in origin of the human races[15]. Testut reported finding the anomaly in 1 per cent. of his specimens, and Gruber in 2.7 per cent. A familial incidence has been reported in numerous instances[8,13].

The close anatomical relationship of the median nerve to the supracondyloid process would lead one to expect occasional sensory or motor disturbances in that nerve. In 1929 Solieri reported a nineteen-year-old male who had median-nerve symptoms,—severe paraesthesia and hypaesthesia of the hand and fingers, caused by the presence of the supracondyloid process. Following operation in this case the neuralgia disappeared immediately,

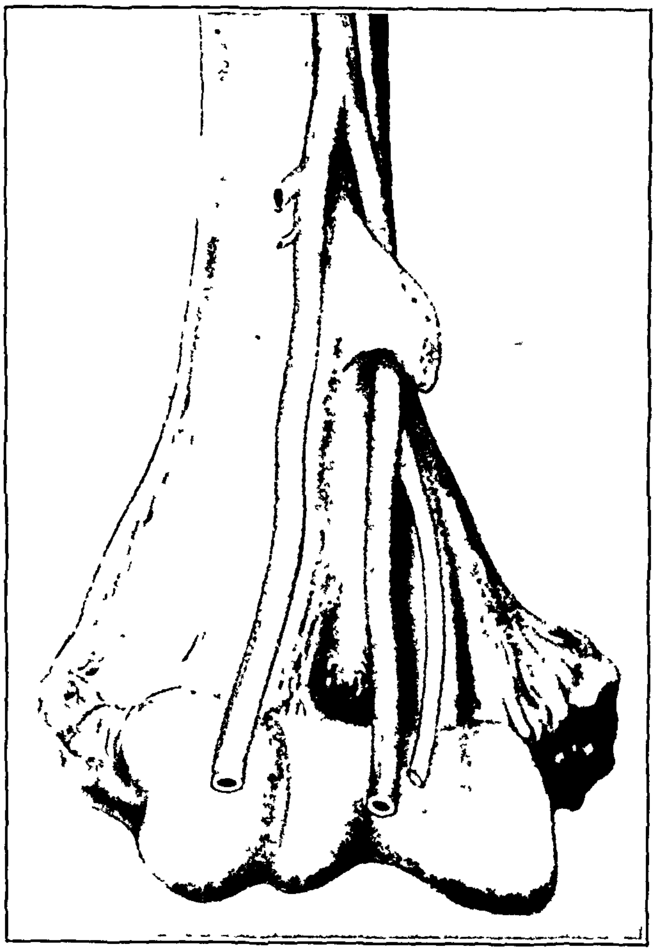

FIG. 1

FIG. 2

Fig. 1: Shows the relationship to the supracondyloid process of the brachial artery, its branches, and the median nerve. (*Reproduced, by permission, from La Chirurgia degli Organi di Movimento,* 24: 123, 1938.)

Fig. 2: Roentgenogram of Mandruzzato's Case 4, showing calcified ligamentous band extending from the supracondyloid process to the medial epicondyle. (*Reproduced, by permission, from La Chirurgia degli Organi di Movimento,* 24: 128, 1938.)

but it returned in a milder form six months later. A bony spur regenerated from the periosteum in this case.

In 1938 Mandruzzato reported five cases. Cases 1, 2, and 3 were patients in whom the supracondyloid process was an incidental finding, noted on physical or roentgenographic examinations for other conditions. The bony spurs were asymptomatic. Mandruzzato's Case 4 was an Italian male, twenty-six years of age, who complained of weakness of the left arm and tingling in the area of the median nerve. This pain became so severe that the patient was unable to work. Complete extension of the elbow and pronation of the forearm increased the pain. The supracondyloid process was palpable six centimeters above the elbow, and there was slight hypaesthesia to pain, touch, and temperature change in the area of the median nerve, with loss in strength of the grip of the hand. Roentgenograms showed the triangular bony spur to be in the usual location (Fig. 2). Mandruzzato stated that on the film one could see clearly a shadow, which extended from the apex of the bony process downward in a curve to its attachment at the margin of the epitrochlear. He felt there was no doubt that this band of tissue was attached to the supracondyloid process. His diagnosis was neuritis of the median nerve, due to the supratrochlear process. At operation Mandruzzato found the patient's median nerve to be in close contact with the supratrochlear fibrous band and with the pronator teres. The bony spur was dissected with its periosteum. The patient's symptoms were relieved and there was no recurrence.

In Mandruzzato's Case 5 a woman, thirty-three years old, complained of severe pain in the area of the median-nerve distribution of the right forearm and hand, aggravated by

even slight movement of the elbow. Thirty years previously, at the age of three, she had injured the right elbow. Three months before admission her right arm was injured, and she subsequently noticed lancinating pain along the flexor surface of the forearm. On examination, a bony spur was found on the medial aspect of the right arm, five centimeters above the epitrochlear. Below it, he states, was a nearly round nodule of irregular outline, hard in consistency and producing a crunching sound when rubbed against the supra-epitrochlear process; all movements of the nodule in the area examined produced pain, which followed the distribution of the median nerve, pain also going up toward the shoulder. Roentgenograms disclosed an old fracture near the apex of the supratrochlear process. This finding was confirmed at operation, when the spur and the fragments were excised. There was complete relief after the operation.

In both patients operated upon by Mandruzzato, the anomaly of the pronator teres was noted, and he concluded that the bony prominence had great effect on the median nerve because, during muscle contraction of the pronator teres, it is impinged by compression on the supra-epitrochlear canal. He recommended removing the periosteum, together with a part of the muscle fibers of the pronator teres, to avoid maintaining irritation to the median nerve by contraction of the muscle.

CASE REPORTS

Three patients with the supracondyloid process have come under our observation.

CASE 1. A lieutenant colonel in the Medical Corps had noted for many years the presence of a small bony prominence on the medial aspect of his left arm, six centimeters above the epicondyle. There was no history of injury, and no associated symptoms. On roentgenographic examination, a small but well-developed supracondyloid process was found. Routine anteroposterior and lateral films failed to reveal the spur, but the oblique film showed it clearly (Figs. 3-A and 3-B).

FIG. 3-A

FIG 3-B

Fig 3-A: Case 1. Oblique view.

Fig. 3-B: Routine anteroposterior view fails to show the supracondyloid spur, which was demonstrated in Fig. 3-A.

Fig. 4

Case 2. Oblique view shows supracondyloid bony spur of humerus.

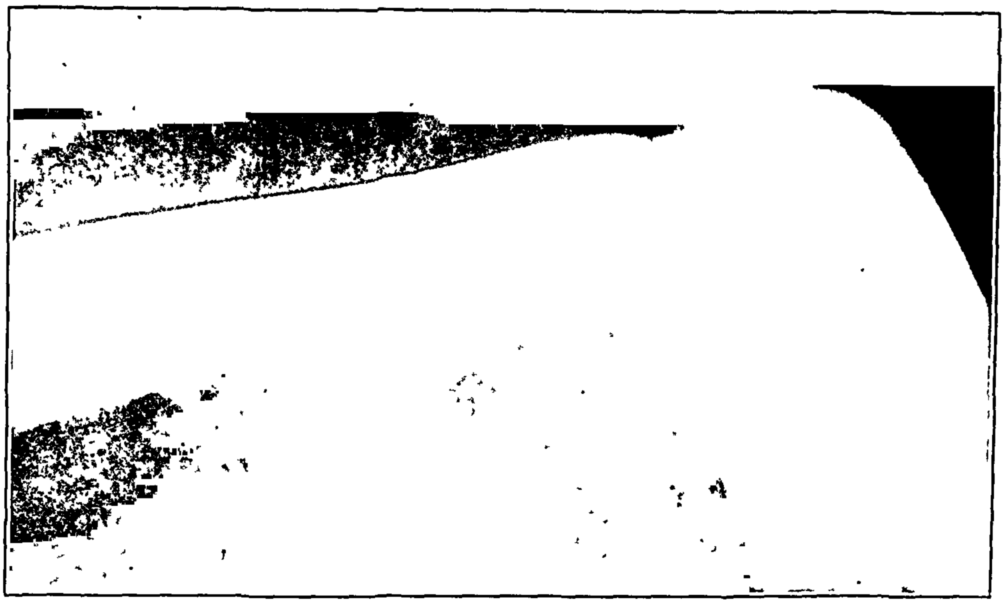

Fig. 5-A

Fig. 5-B

Case 3. Anteroposterior and lateral views.

CASE 2. A private first class, thirty-two years of age, was seen in consultation in the Orthopaedic Clinic, complaining of pain in the right arm and forearm, radiating to the median-nerve area in the hand. There was no history of injury; the pain was not very severe. A bony spur was palpable on the medial and anterior aspects of the right humerus, 5.5 centimeters above the elbow. Pressure beneath it reproduced this pain. Routine anteroposterior and lateral roentgenograms failed to show the bony spur, but it was well visualized on an oblique film (Fig. 4). Because of the mild nature of the symptoms and the absence of atrophy or hypaesthesia, operation was not advised.

CASE 3. A nineteen-year old private in the Infantry complained of pain, weakness, and numbness of the left arm and hand, and of pain in the left shoulder. One month before admission to the hospital, he had been injured by the blast of an exploding artillery shell, which caused him to fall on his left shoulder. There was swelling and limitation of motion at the shoulder, but roentgenograms showed no evidence of bone injury or dislocation of the shoulder. One month later he was still complaining of pain in the left shoulder, left arm, and forearm, radiating to the area of median-nerve distribution in the hand. This pain was severe, and was aggravated by extending the elbow and pronating the forearm. There was a normal range of motion at the shoulder, and no evidence of injury. Six centimeters above the medial epicondyle a bony spur was palpable, and pressure in this area caused paraesthesia in the median-nerve distribution, duplicating the patient's complaint. There was no hypaesthesia and no evidence of motor impairment of the nerve. Roentgenograms confirmed the presence of the supracondyloid bony spur on the anteromedial aspect of the lower part of the humerus. At operation, the spur was found to have an overlying bursa, measuring one centimeter in diameter. The branchial artery and the median nerve passed beneath the spur, to which was attached a slip of muscle from the pronator teres. The bony spur and its periosteum were resected in the manner recommended by Solieri and by Mandruzzato. The patient was immediately relieved of all pain, and was sent to general duty twenty-eight days after the operation (Figs. 5-A and 5-B).

SUMMARY AND CONCLUSIONS

1. The supracondyloid process, when present, is often associated with a tendinous band, which is attached to the medial epicondyle, and with an anomalous origin of the pronator teres.

2. The supracondyloid process can cause a syndrome characterized by pain, radiating from the shoulder to the median-nerve area of the hand. This pain is increased by pronation of the extended forearm.

3. The diagnosis is easily made by palpation, but routine anteroposterior or lateral roentgenograms may fail to show the spur, because of its position on the anteromedial aspect of the bone. An oblique view may be required.

4. Solieri and Mandruzzato have reported three cases in which relief followed resection, and one additional case of resection is reported here.

5. In resection of the bony spur, it is emphasized that removal of the periosteum of the spur and the binding fibers of the pronator teres should be done to prevent regeneration of the spur and the recurrence of symptoms.

NOTE: The authors wish to express their appreciation to Dr. J. H. McGregor, Professor Emeritus, Department of Zoology, Columbia University, for his aid in preparing this article.

Photography was done by Staff Sergeant Carl V. Smith, Medical Detachment, Woodrow Wilson General Hospital, Staunton, Virginia.

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OSTEOTOMY OF THE LUMBAR SPINE FOR CORRECTION OF KYPHOSIS IN A CASE OF ANKYLOSING SPONDYLARTHRITIS

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INTRODUCTION

Gradual or manipulative correction of kyphosis in cases of advanced ankylopoietic spondylarthritis has been widely employed for many years, with discouraging results. Corrections have been uniformly incomplete; they were not without danger; and eventually the deformity nearly always recurred. The roentgenograms and photographs of a patient suffering from this disease are shown in Figures 1-A, 1-B, 2, and 5-A. This man's urgent wish to become erect and his otherwise healthy, vigorous condition prompted the author to devise a method of operative correction through section of both the anterior and posterior elements of the vertebral column. The operation, when performed upon the cadaver, gave promise of being safe and feasible; and it proved to be effective in achieving correction. It was then successfully performed upon this patient; satisfactory correction

Fig 1-A

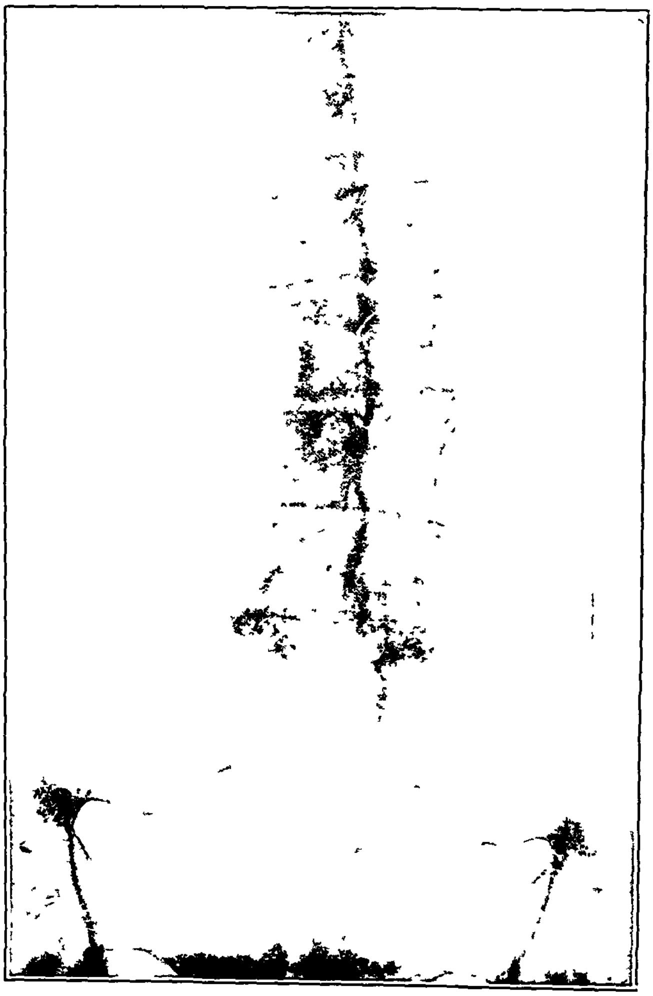

Fig 1-B

Lateral and anteroposterior views of the vertebral column in 1940.

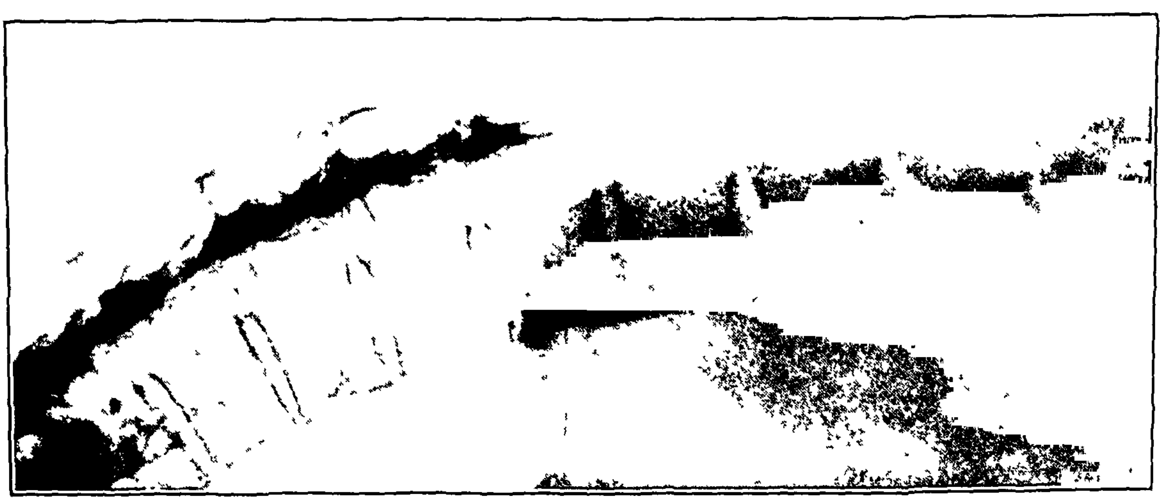

Fig. 2

Fig. 3

Fig. 2: Appearance of the vertebral column in 1944, a short time before operation.
Fig. 3: Three months after operation.

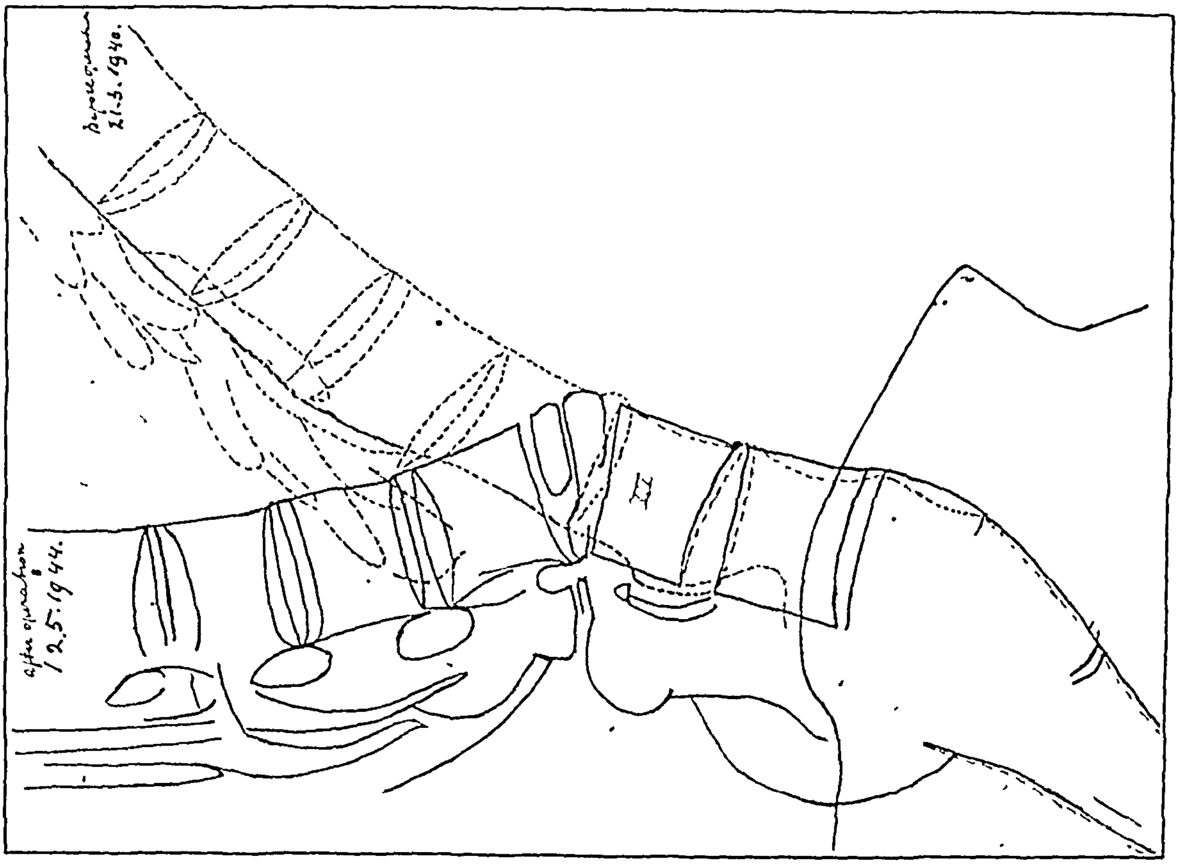

Fig. 4

Outlines of vertebral column, before and after operation.

was obtained (Figs. 3 and 5-B) without untoward incident; and the result more than two years later was gratifying (Fig. 7).

PATHOLOGICAL FACTORS

A study of the roentgenograms indicated bony ankylosis of the posterior articulations between the thoracolumbar and lumbar vertebrae, as well as ossification of the anterior longitudinal and interspinal ligaments throughout the lumbar region and part of the thoracic region. That ankylosis was not complete was apparent, since the patient was more erect in the morning than in the evening. He was conscious of this change of posture, which is one not uncommonly observed, even in the more advanced stages of the disease[5]. Ankylosis proved to be such, however, that nothing could be accomplished toward correction of the deformity by non-operative means,—including exercises, suspension, recumbency in extension, a plaster jacket, and a corset. (Actually, as was demonstrated later at operation, extensive fibrosis and partial ossification of ligaments were found posteriorly, making identification of bony structures difficult. Anteriorly about the vertebral bodies, the ossified portion of the ligament was found to vary from the thickness of thin paper to that of thick paper.) In view of the pathological changes, it seemed necessary for successful correction that both the anterior and posterior elements of the vertebral column be freed, since each was involved in the ankylosing process.

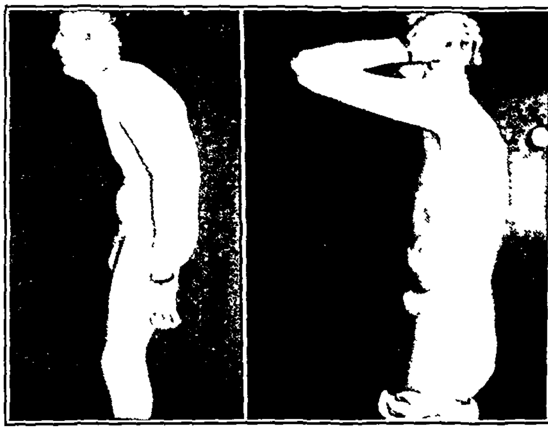

FIG. 5-A FIG. 5-B

Fig. 5-A: Before operation. Patient straightens himself as much as possible, bending his knees so as to shift the center of gravity backward.

Fig. 5-B: After operation. The photograph again shows a compensatory lordosis under the kyphosis.

MECHANICAL FACTORS

Abnormal skeletal curvature can be corrected by osteotomy, if the involved bone is surgically accessible, and if the nature of the disease producing the curvature and the patient's general condition permit. A compensatory angulation at the site of osteotomy corrects the malalignment. The osteotomy may be performed at several points or, preferably, at one. If the ankylosed vertebral column is considered as one bone, the use of the term osteotomy seems justified to describe surgical section of the column for the purpose of correcting deformity. The site and type of osteotomy must be such that injury to the spinal cord and its nerves will be avoided, and that sufficient correction of the deformity will be obtained. The axis of motion, or hinge point, during angulation of the osteotomized column will be at the posteriormost point of contact of the vertebral bodies immediately above and below the site of osteotomy,—that is, their adjacent posterior borders. A sufficient quantity of bone posterior to the vertebral canal must be removed, and the intervertebral disc must be sectioned anteriorly in order to permit correction. Theoretically, when the vertebral column has been sectioned in this manner and an adequate compensatory anterior angulation has been obtained, the sectioned disc should gape anteriorly and the margins of the osteotomized neural arches should come together posteriorly. This is exactly what occurred in the cadaver,—the sections of the divided vertebral column moved upon each other in flexion and extension about the adjacent posterior borders of the freed vertebral bodies as if on a hinge.

The second and third lumbar vertebrae are favorable sites of osteotomy, since they lie

caudal to the spinal cord, are outside the more rigid thoracic region, and are sufficiently near the mid-point of the kyphotic curve.

A roentgenographic tracing of the curve of the patient's vertebral column, used as a pattern, showed that the removal of 3.5 centimeters of the extreme dorsal bony elements would allow a gap on the ventral side of the column sufficient for correction. Allowing for the roentgenographic magnification, a little less bone could be removed in reality.

Forward displacement, during correction, of the vertebra above the osteotomy onto the vertebra below appears to be possible. Following extensive laminectomies in individuals with weak muscles and lax ligaments, especially if the posterior articulations are weakened or removed, spondylolisthesis may develop. This is generally of slight degree. It was thought that in this case the danger could not be very great, because the posterior longitudinal ligament would be thick and hard. To provide against this complication, the posterior ligamentous elements of the disc—including the posterior longitudinal ligament—must not be divided. Actually, these posterior ligaments were left intact, both in the operation upon the cadaver and that upon the patient, and no forward displacement occurred.

Following osteotomy in the cadaver, the dura was opened and the cauda equina was widely exposed. The vertebral column was then angulated anteriorly and posteriorly, and the nerve roots were inspected. No encroachment upon the lumen of the vertebral canal occurred, and the spinal cord and nerve roots moved freely in the unchanged meningeal compartment.

OPERATIVE TECHNIQUE

The operation must be performed in two stages. The first stage involves the removal of the laminae of the second lumbar vertebra and of the posterior articulations between that and the third lumbar vertebra. The second stage, performed through an anterior approach, is concerned with the excision of the second lumbar intervertebral disc, the angulation of the column, and the fixing of bone grafts in the gap between the two vertebrae.

Stage I

The first stage, performed January 26, 1944, can hardly be claimed to be a new operation, although the combined excision of the laminae and the articulations on both sides is not a common one. Identification of the spinous processes of the first, second, and third lumbar vertebrae proved especially difficult, because of the ossification of the interspinal ligaments, so that roentgenographic localization was necessary. Local anaesthesia (novocain and adrenalin) was used, with the patient lying prone, propped with pillows. The three spinous processes were laid bare and excised. Difficulty was encountered in identifying and freeing the laminae and articulations and in exposing the intervertebral notches, owing to the formation of fibrous tissue and to partial ossification. Hemorrhage was also present, and its control required time and patience. Following complete laminectomy of the second lumbar vertebra, the articulations on each side between the second and third lumbar vertebrae were identified; and the four articular processes were completely removed, special care being taken to avoid injury to the roots, ganglia, and nerves lying immediately anterior in the intervertebral notches.

The postoperative course was uneventful. The temperature did not rise above 38.1 degrees centigrade. Two weeks after operation, the hemoglobin was 85 per cent., erythrocytes 4,100,000, leukocytes 9,500, and thrombocytes normal. The blood pressure was 130/80.

Stage II

The second stage was performed on February 11, 1944, under general anaesthesia. With patient lying on the right side, a transverse abdominal incision, similar to that of Péan, made a little above the umbilicus, opposite the second lumbar intervertebral disc.

This incision can easily be made large enough, with slight damage to muscles. Following reflection and retraction of the peritoneum and its contents, a large part of the lumbar vertebral column could be seen quite well, as is often observed in operations for horseshoe kidney and in extraperitoneal lumbar ganglionectomy. The approach from the left is easier than that from the right, for the aorta and the vena cava, lying somewhat to the right, can be displaced in that direction, making possible direct palpation of both sides and the front of the vertebral bodies. The lumbar arteries and veins traverse the vertebral bodies midway between the discs, and can readily be avoided. Because the disc is avascular, hemorrhage was avoided. The disc was exposed and excochleated throughout most of its extent anteriorly, but its posterior wall was not touched, as previously emphasized.

The patient was then carefully placed in the supine position by turning the operating table on its long axis. As the supporting pillows were removed, the back was gradually released and, through the action of gravity, was straightened until it rested upon the table; thus the deformity was satisfactorily corrected. The lateral position was then restored by turning the table; and pieces of bone, removed from the tibia with the motor saw, were packed into the gap which had appeared between the bodies of the second and third lumbar vertebrae. The wound was closed.

A double plaster spica from axillae to

FIG 6
Vertebral column in 1945, one year after operation

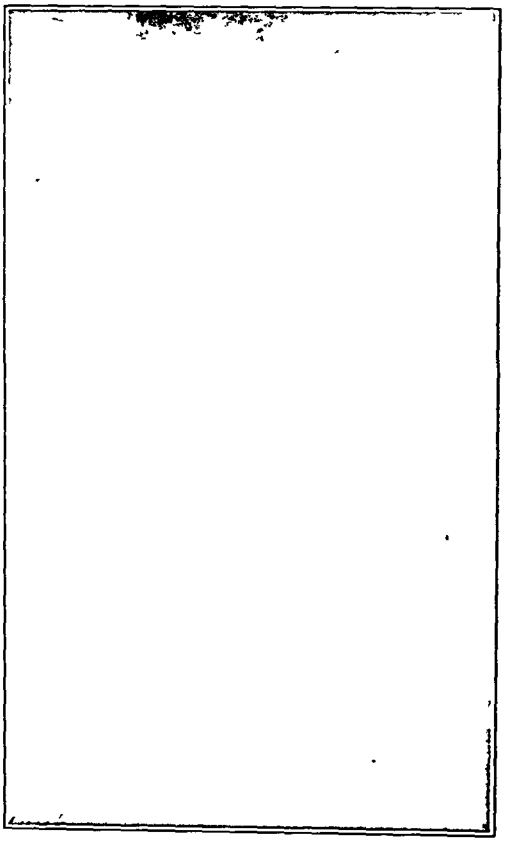

FIG 7
Roentgenogram taken two years after operation.

knees was then applied, as the patient lay supine on a flat metal band. This band rested at one end on the head of the operating table; at the other end it was supported by an assistant. When the plaster had hardened, the band was removed.

Again the postoperative course was uneventful. The temperature did not rise above 37.8 degrees centigrade. During the first day, the pulse rose to 130 per minute; the minimum blood pressure was 95/75. There was slight subcutaneous emphysema of the scrotum. No neurological disturbances were observed.

PATHOLOGICAL EXAMINATION

The pathological examination (made by Dr. Rudolf Van Dam) was reported as follows: "Histologically the pieces of intervertebral disc are found to consist of normal fibrocartilage, which does not contain many cells and in places gives the impression of being somewhat degenerated cystically. This latter finding is not quite clear, however. There is no proliferation in the blood vessels nor of the connective tissue. There were a few pieces of bony tissue [of the anterior longitudinal ligament], of which a section was not made."

AFTER-CARE

The patient remained recumbent in the plaster spica for three months. Lateral and stereoscopic anteroposterior roentgenograms were then made (Fig. 3), after which a plaster jacket was applied, and the patient was allowed gradually to become ambulatory. He was discharged to his home three and one-half months after the operation. The full jacket was removed at the end of six months, after which he wore a light one for several months longer as a precaution.

END RESULTS

Roentgenograms taken eleven and twenty-five months after operation are shown in Figures 6 and 7, respectively; the photograph at the completion of treatment is shown in Figure 5-B. The patient is completely satisfied. No return of the deformity has occurred during two years.

LITERATURE

In operating upon the lumbar vertebral bodies, Huc used a variation of the method first described by Treves, in 1892. The approach was made through an incision along the lateral border of the erector spinae. The transverse processes were resected, and access to the bodies was thus obtained. The roots of the lumbar plexus intervened posteriorly, however, and the psoas intervened anteriorly, so that any procedure through this approach was very difficult.

Ito, Tsuchiya, and Asami, in 1934, described operative procedures on tuberculous thoracic and lumbar bodies, in ten cases. These authors had been impressed by the wide exposure possible in lumbar-sympathetic ganglionectomy. The thoracic approach is difficult, although Peet's operation is encouraging.

The posterior osteotomy of Smith-Petersen, for the correction of deformity arising in this disease, did not come to the author's attention until December 1945, since access to current foreign literature was impossible in the Netherlands during the war years. The six cases of Smith-Petersen show that the anterior portion of the vertebral column gave way sufficiently, following excisions of the posterior structures alone. In the author's case, ossification of the anterior longitudinal ligament apparently prevented correction by simple supine recumbency, following the first stage of the procedure. Great force was not applied, however. Only after section of the disc in the second stage was correction obtained. An advantage of the method of Smith-Petersen is, of course, that it can be performed in one operation. Time and further investigation may disclose which of these

procedures is more suitable, not only in cases of kyphosis but also in other deformities of the vertebral column.

CASE HISTORY

G.P., a cook and restaurant keeper, born in 1900, was well until 1937, when he was struck by a motor car. He was admitted to a hospital in Amsterdam, where the diagnosis of fractured vertebra was made. The roentgenograms taken at that time cannot be found; subsequent films show no evidence of a fracture. After six weeks in the hospital he was discharged; his back was stiff, and he bent forward as he walked. Later the condition was diagnosed as ankylopoietic spondylarthritis, and he was given roentgenotherapy and "injections". He became free of pain in 1939.

In 1940 he was referred to the author for correction of the kyphotic deformity. The erythrocyte sedimentation rate (Westergren) was 46 millimeters per hour. The roentgenograms and photograph taken at that time are shown in Figures 1-A, 1-B, and 5-A. The patient was lean, but quite healthy. No other joints were affected. He was given a course of gold therapy. The sedimentation rate later fell to 29 millimeters; by 1944 it was 14 millimeters per hour.

Attempts were made to correct the deformity by exercises, traction, and recumbency in extension; supports included plaster jackets and a corset. These did not avail, except that the corset gave indispensable support. He complained constantly of the pressure of the corset, although he could not work without it. He repeatedly requested surgical intervention to correct the deformity.

The first stage of the operation was performed January 26, 1944; the second stage on February 11, 1944.

Since the operation, the patient has been under observation for two years. He has remained symptom-free as far as his back is concerned, and he is satisfied with the result obtained.

In October 1944 he suffered an attack of rheumatoid arthritis with involvement of the left hip and shoulder, which cleared up during the administration of salicylates and warmth. By February 1945 he was again well. The sedimentation rate fell from 23 millimeters, in October 1944, to 13 millimeters. It is probable that the poor nutrition which prevailed in the Netherlands, together with the lack of fuel and a great sorrow in his family, were responsible for this attack. There has been no return of the deformity.

DISCUSSION

The first stage of the operation was rather laborious and tedious, requiring much patience, whereas the second operation went more smoothly in all respects than had been expected, especially as regards the loss of blood. Nevertheless, whenever it is proposed to perform the operation, all features will have to be weighed and checked extremely carefully, step by step. Every phase of the operation is under control, however, and it can be interrupted during any phase. The indications for it are rare in spondylarthritis: The case must be a resistant one, as far as the vertebral column is concerned; and the patient must be in good health and not too old. The condition of the other joints should be considered. It is not an operation to be undertaken lightly. It may be, however, that modifications of the operation, in either of the two stages, can be applied in other cases. This may be possible, for example, with kyphoses of a different nature, as in the congenital form, when pressure of the medulla on the curvature may lead to paralysis. Laminectomy, which is sometimes performed in the latter group, is really an illogical operation. unless the kyphosis is removed. In certain other cases of kyphosis and also of scoliosis, the two-stage operation may be considered, but it is seldom indicated. In regard to scoliosis, the operation has so far been performed only on the lumbar region and on cadavera; the results are encouraging.

The easy accessibility of the lumbar vertebral bodies and discs suggests the applicability of this operation in rare cases of vertebral fracture and of isolated tumors. It seems quite possible that, in hernia of the disc, the entire disc can be removed and replaced by bone grafts, as in Stage II. These considerations raise the question of whether the technique of the operation cannot be further improved—especially as regards details in the fixation of the transplanted bone—and its applications extended.

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RECURRENT DISLOCATION OF THE FIRST CARPOMETACARPAL JOINT REPAIRED BY FUNCTIONAL TENODESIS

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From the Orthopaedic Department, New York Polyclinic Medical School and Hospital

Recurrent dislocation between the base of the first metacarpal bone and the greater multangular is rare, and it has not been mentioned until recently in textbooks. Bennett's fracture complicated by dislocation in this joint, or acute dislocation with fracture of the base of the first metacarpal, is more common. In the case described here, there had been an acute dislocation in this joint, which had been reduced and had recurred, and the reduction could not be maintained by the closed methods of treatment.

A review of the literature disclosed three procedures which have been used for this condition. Bunnell has described a method of "lashing the metacarpal to the trapezium with a strip of tendon or fascia through drillholes". Slocum reported one case in which he used a tendon graft from the palmaris longus, pulling it through volar drill holes made in the base of the thumb and the greater multangular. Eggers described a case in which he used the lateral portion of the tendon of the extensor carpi radialis longus, dividing it, and inserting this divided band into the base of the metacarpal of the thumb through drill holes. The operation described here offers a new approach to this problem.

CASE REPORT

G. G., a twenty-two-year-old male, was first examined on February 15, 1945. About one year before, he slipped on an icy pavement and fell, landing with a considerable amount of his weight on his extended right arm and the dorsiflexed hand. The palm did not touch the pavement, but only the tips of the extended fingers and thumb. He had severe pain and noticed deformity of the first carpometacarpal joint. The dislocation was reduced and a plaster bandage was applied for three weeks. At the end of this period the patient resumed normal activities, but the bone soon became displaced again. At the time of examination, his complaints were of pain in his thumb and inability to use his hand for working.

Physical examination showed an apparent deformity on the dorsum of the right hand, corresponding to the carpometacarpal joint. The patient demonstrated that he was able to reduce the dislocation, but that the bone would immediately become displaced again. The examiner was also able to effect reduction without difficulty, but noted that the bone would snap out again, with a painful crepitation. The intrinsic and extrinsic muscles of the hand showed no abnormalities.

Roentgenographic films in the anteroposterior, lateral, and oblique planes showed a dislocation of the metacarpal bone over the greater multangular (Fig. 1).

The operation to be described was performed on February 18, 1945, at Polyclinic Medical School and Hospital. This patient returned to his regular work four weeks after the operation. He was seen at intervals thereafter; and at the time of the last examination on April 12, 1946, fourteen months after the operation, he had no complaints. The function of the thumb was satisfactory and no impairment could be detected in the action of the extensor pollicis brevis (Fig. 2).

In devising this operation, the author tried to apply a method by which a living tendon transplant would support a capsular repair in order to maintain the corrected position of the dislocated bones. In selecting the tendon, the following points had to be considered:

1. The tendon should have a logical anatomical course to justify its selection.
2. The function of the muscle should actively hold the involved bone in place.

FIG. 1

Roentgenograms show the dislocation of the first metacarpal over the greater multangular.

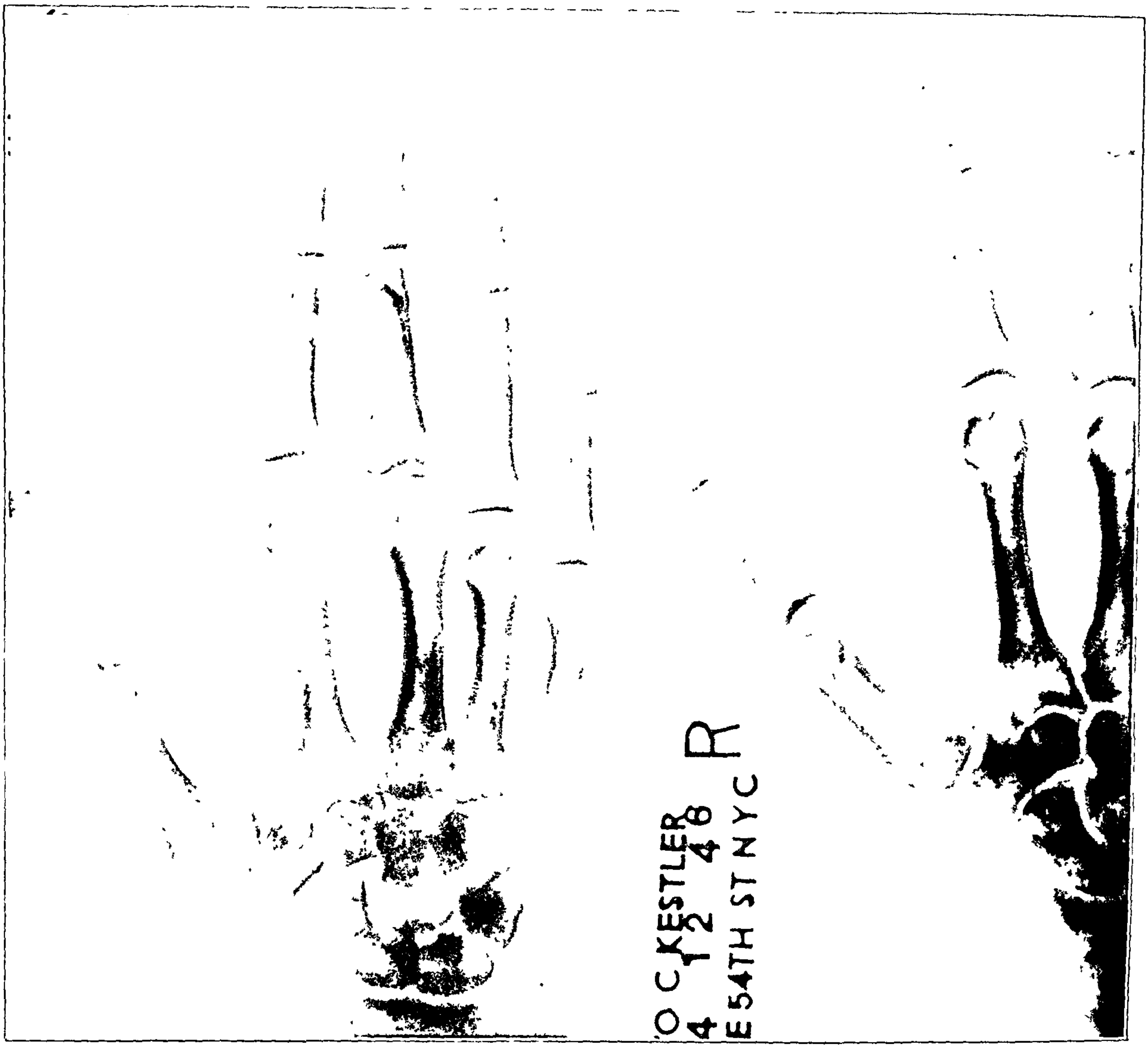

Fig. 2

Anteroposterior and oblique roentgenograms, fourteen months after the operation, show what may be considered a satisfactory end result.

3. The procedure should not interfere with the original function of the tendon. These requirements were fulfilled in the case reported.

OPERATIVE PROCEDURE

With the hand in neutral position, a curved incision was made over the joint between the base of the first metacarpal and the greater multangular (Fig. 3). The incision was about two and one-half inches long, with the convexity to the radial side. By this lateral approach the injury to the dorsal branch of the radial artery could be avoided. The tendon of the extensor pollicis brevis was identified and divided about one-quarter inch proximally to the proximal end of the greater multangular. The base of the first metacarpal bone and the greater multangular were exposed by a sharp periosteal elevator. A drill hole was made in the base of the first metacarpal with a hand drill, and another in the greater multangular with a curved awl. Both holes were enlarged by introducing a wider awl. The distal portion of the tendon of the extensor pollicis brevis was drawn through both holes (Fig. 4). The dislocation was then reduced, and the capsule was sutured. The distal portion of the tendon, which had been drawn through the holes, was sutured to the proximal end of the tendon. Other structures were closed routinely, and anterior and posterior splints were applied to hold the thumb in abduction for three weeks.

Although this procedure was completely satisfactory in this case, after making dis-

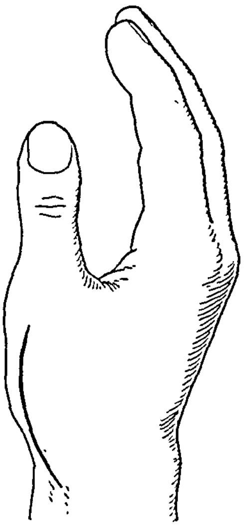

FIG. 3

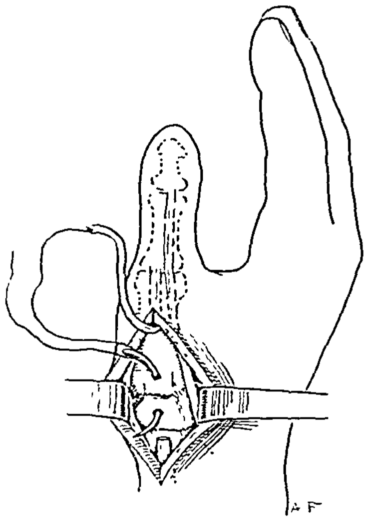

FIG. 4

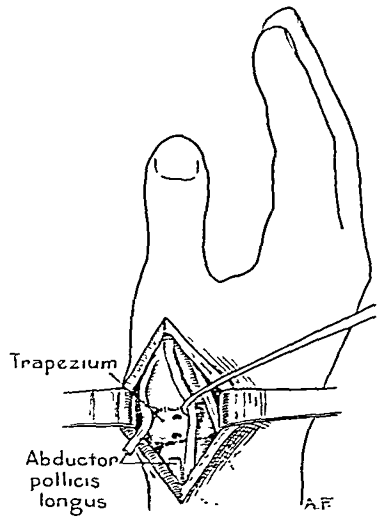

FIG. 5

Fig. 3: A curved incision is made, with the hand in neutral position.

Fig. 4: The distal portion of the extensor pollicis brevis tendon is pulled through the drill holes in the base of the metacarpal and the hole in the greater multangular.

Fig. 5: The distal portion of the abductor pollicis longus tendon is pulled through the holes in the greater multangular.

sections for the study of the function of the muscles of this area, the author feels that the use of the abductor pollicis longus would be more physiological than the use of the extensor pollicis brevis. When the abductor pollicis longus is used, a hole is tunneled through the greater multangular with an awl, and the distal portion of the cut tendon (Fig. 5) is drawn through and united with the proximal portion.

The following reasons are offered for the use of the abductor pollicis longus:

1. The abductor pollicis longus is attached to the base of the metacarpal; therefore it may be extended through the hole made in the greater multangular.

2. The function of this muscle, with its normal pull, is much more adequate in keeping the reduced metacarpal bone in place.

This procedure would be called transposition and extension of the insertion of the tendon of the abductor pollicis longus.

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NON-UNION OF THE ISCHIAL TUBEROSITY ASSOCIATED WITH EPIPHYSITIS VERTEBRAE

Report of a Case

BY LIEUTENANT COMMANDER WALTER SCOTT

Medical Corps, United States Naval Reserve

McMaster[1] recently reported a case in which the secondary ossification center of the ischium had failed to fuse with the parent structure. His patient was a nineteen-year-old Marine, whose symptoms were recurrent and were localized to the hip area; apparently no other abnormal findings were disclosed by the physical examination or the laboratory data.

Recently a similar case was discovered which, in addition to the ischial findings, showed other signs of osteochondritic dysfunction. Because of these associated changes, and because the available literature on this subject is meager, a further discussion of the disease, with the report of an additional case, seems justified.

CASE REPORT

J.E.B., aged twenty-two, a Private First Class in the Marine Corps, was admitted to a United States Naval Hospital on September 23, 1945, just after he had been evacuated from the South Pacific Area. His chief complaint was pain in the thoracic spine.

Fig. 1

Showing round-hollow back, with increase in lordosis and forward thrust of the neck.

When the patient was fifteen years of age he had poor posture. At that time he "pulled something" in his right hip while playing baseball, and the hip was sore for about a week. He did not go to bed or have any medical attention; a complete recovery followed.

While engaged in battle as a flame-thrower, in September 1944, the patient's back became painful. He was seen by a medical officer, who found the right leg to be one and one-half inches shorter than the left leg. Treatment consisted of elevation of the right heel and routine physiotherapy; but the patient's complaints persisted, and he was evacuated to this Naval Hospital for further care.

The findings at physical examination were as follows: The patient was a white male, six feet one inch in height, who weighed 192 pounds, and walked with a slight right-sided limp. The hair was of scanty distribution. His shoulders were level; the right side of the pelvis was one and one-half inches lower than the left, because of shortening of the right femur. The tibiae were of equal length. Motions of the spine were within normal limits. There was mild tenderness to heavy tapping along the thoracic spinal muscles.

Four determinations of the basal metabolic rate were taken, several days apart, and they were minus 25, minus 24, minus 10, and minus 4, respectively. Other routine laboratory studies, including the Kahn test, were normal.

The roentgenographic findings were as follows:

1. An anteroposterior view of the pelvis (Fig. 2) showed that the secondary ossification center of the left ischium had failed to fuse. The mass was saucer-shaped and measured 6 by 3.75 by 3.75 centimeters along its triangular margins. Two smaller nodules, ovoid in shape, were visible; one, 2.5 by 1.2 centimeters in size, lay postero-inferiorly to the acetabulum; another was attached to the tip of the main mass, and measured 1 by 1.2 centimeters in size. A few cystic changes and some irregularities were noted in and about the ischium.

2. A lateral view of the thoracic spine (Fig. 3) showed wedging throughout the thoracic area as a result of an old epiphysitis. The typical round-hollow back was evident.

3. Views of the right wrist, the right knee, and the hips were normal in appearance.

Fig. 3

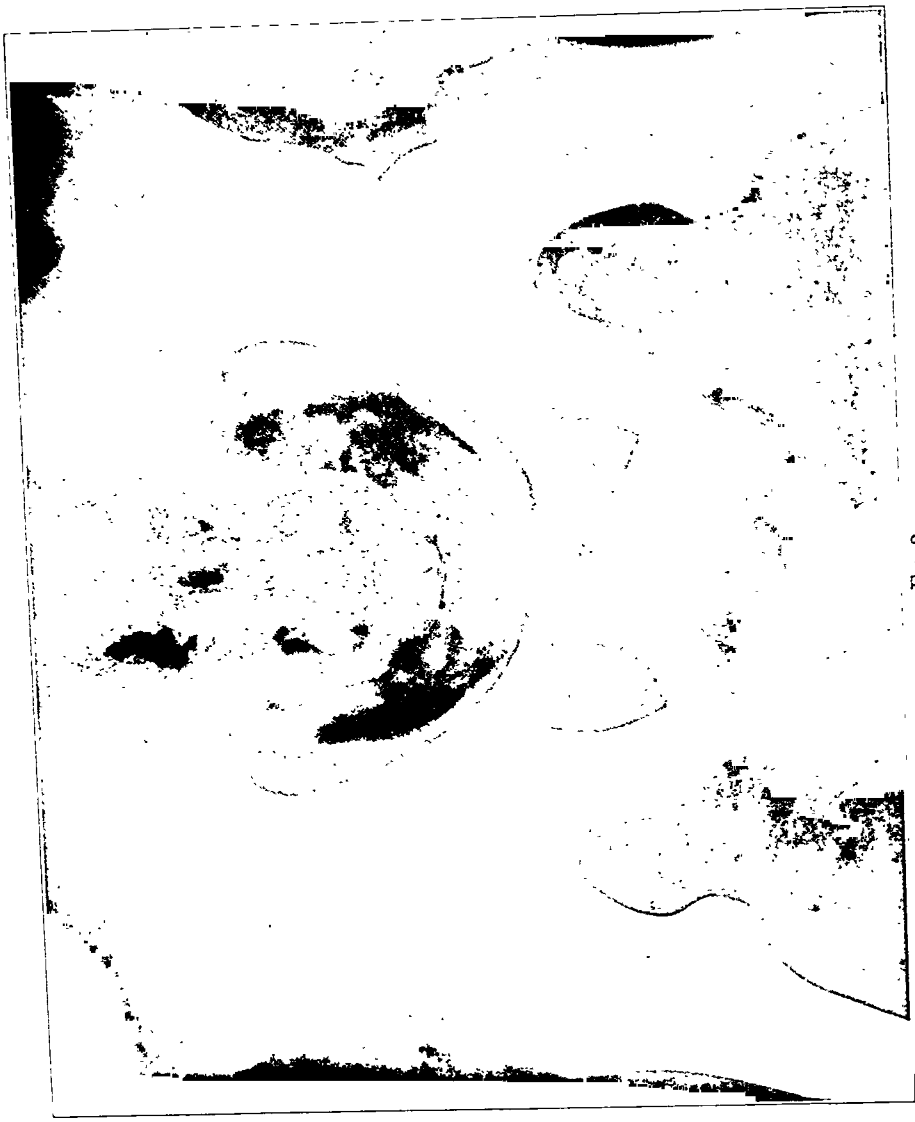

Fig. 2

Fig. 2: The secondary ossification center has failed to unite. Fragmentation, sclerosis, and bony irregularities are noted. No evidence of bony union can be determined.

Fig. 3: Lateral view of the thoracic spine, showing widespread wedging as a result of an old osteochondritis.

COMMENT

No explanation for the shortening of the right leg could be found, either in the history or in the physical examination. The painful thoracic spine was, in all probability, due to faulty mechanics, and not to any activity of the osteochondritic process. The ischial lesion was entirely asymptomatic, and was found purely by accident. The extensive changes in the thoracic spine, coupled with the failure of the ischial secondary center to fuse, would suggest the possibility of some systemic factor. Two basal metabolic readings of minus 24 and minus 25 may be significant in the etiology, although there were no outstanding symptoms or signs to substantiate a diagnosis of frank hypothyroidism, other than sparse hair distribution and a consistently slow pulse.

CONCLUSIONS

Failure of the secondary ossification center of the ischium to unite with the diaphysis is possibly a part of a general osteochondritic dysfunction. In the case presented, it was associated with a moderately severe, but healed, osteochondritis of the thoracic spine and a short femur of undetermined origin; there was a history of a short leg in the father.

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TRANSPLEURAL RUPTURE OF A TUBERCULOUS SPINAL ABSCESS TREATED SUCCESSFULLY BY STREPTOMYCIN *

Report of a Case

BY CHARLES MORGAN, M.D., AND DAVID M. BOSWORTH, M.D., NEW YORK, N. Y.

From the Orthopaedic Service, St. Luke's Hospital, New York City

The following case of tuberculosis of the spine with a large paraspinal abscess is reported because, in spite of rupture of the abscess into the lung and the resultant spread of lesion, the patient survived. The authors believe that recovery may be attributed to the administration of streptomycin.

CASE REPORT

A male physician, thirty-five years old, entered the Armed Services in June 1942. At that time tuberculin tests and roentgenograms of the chest were negative. He was in good health until June 1943, when, while stationed in Tunisia, he received a blow on the right chest. The patient experienced severe chest pain, malaise, and hemoptysis. After this he had two episodes of sudden, severe pleuritic pain, associated with hemoptysis of three or four days' duration. In September 1943 he returned to the United States; at that time a sputum examination was positive for tubercle bacilli, and the patient was admitted to Fitzsimmons General Hospital. He remained there under treatment until March 1944, when he was discharged from the Army.

* Presented at the meeting of the New York Academy of Medicine, New York City, October 1945.

At the time of his discharge the patient noted the insidious onset of neck stiffness, which was present particularly while he was seated for meals or shaving; it was relieved by moving his neck about. This condition gradually became worse, and the patient returned to Fitzsimmons General Hospital in June 1944.

One month later, fullness was noted in the neck, along the anterior border of the right sternocleidomastoideus. Roentgenograms of the spine at that time were reported as negative. A chest roentgenogram showed a paramediastinal shadow on the right. The symptoms of pain and stiffness increased and a torticollis appeared, with the head tilted to the left. Roentgenograms of the spine, taken in August, were still reported as negative. The surgical diagnosis was cervical lymphadenopathy. A biopsy was carried out, revealing a cervical paraverterbral abscess, and the incision was packed open. Following this the patient received 25,000 units of penicillin intramuscularly every three hours for two weeks, with no

FIG 1-A

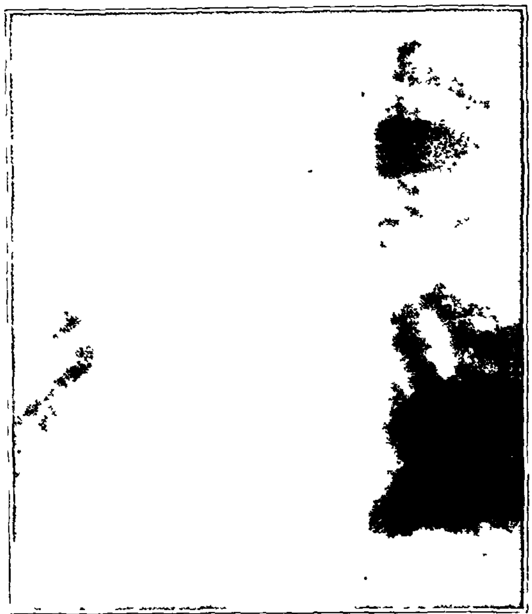

FIG. 1-B

Fig. 1-A: Shows tuberculosis of cervical spine, with abscess shadow anterior to vertebral bodies, extending from occiput downward into thoracic area.

Fig. 1-B: Shows shadow of bilateral abscess in upper thoracic region, with some narrowing of intervertebral spaces and sclerosis of vertebral bodies

FIG. 1-C

Abscess can be seen in right ilium.

effect. The pain in the neck became so marked that he was placed in a jacket which included the head and neck. Roentgenograms now were interpreted as showing a tuberculous lesion of the cervical spine. The patient was transferred to St. Luke's Hospital.

Fig. 2-A

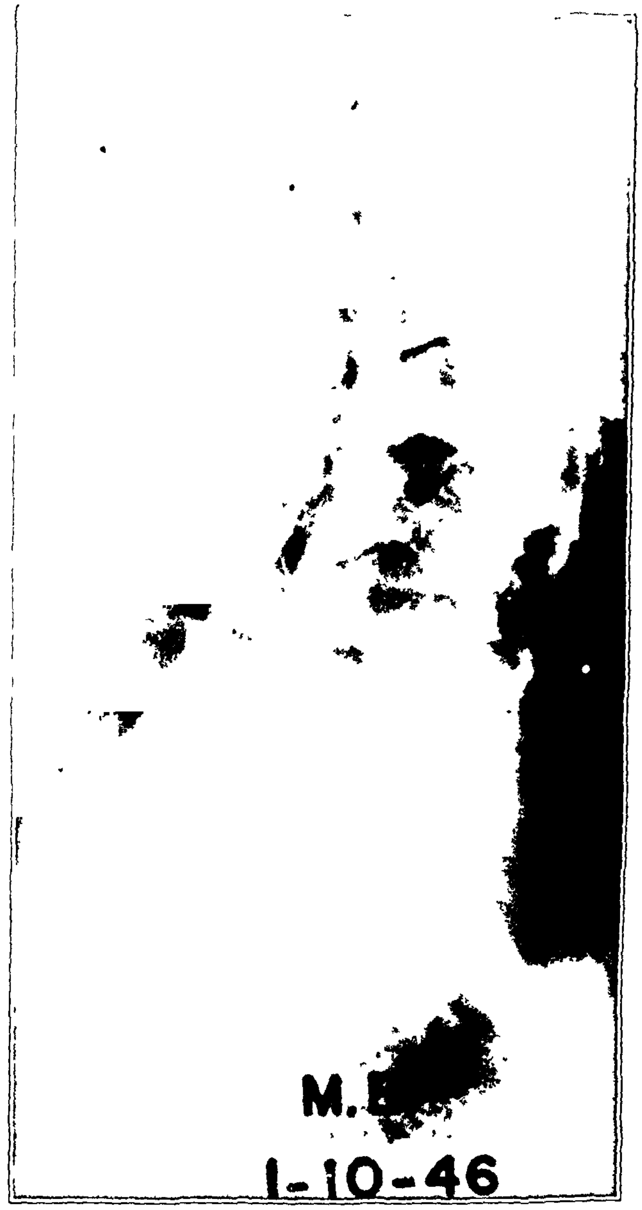

Fig. 2-B

Recent roentgenograms show solid fusion of spine from occiput to tenth thoracic vertebra, and healing of lesions of vertebral bodies, with beginning synostosis in the cervical region.

Fig. 2-C

Shows advanced healing of abscessed right ilium.

Admission examination at St. Luke's Hospital showed a chronically ill male. who had swelling of the right side of the neck and a draining sinus. There was marked spasm of the paraspinal muscles, with limited motion. Percussion and auscultation of the chest failed to indicate pathological changes.

Laboratory studies showed no acid-fast bacilli in the sputum or urine. Cultures of material taken from the cervical sinus yielded hemolytic *Staphylococcus aureus*; and, later, a positive guinea-pig test for tuberculosis was obtained. Mild anaemia and leukocytosis were present.

Roentgenograms of the entire spine (Figs. 1-A, 1-B, and 1-C) disclosed slight narrowing of the intervertebral discs from the second to the sixth cervical vertebrae, with areas of irregular sclerosis and bone destruction of the anterior borders in the same region. There was marked widening of the pre-

FIG. 3-A

FIG. 3-B

Fig. 3-A: Roentgenogram of the chest, before rupture of the abscess.

Fig. 3-B: Roentgenogram taken two days after rupture of the abscess. Shows generalized infiltration of both lungs and decrease in abscess shadow.

vertebral soft tissues, extending from the occiput down into the mediastinum on the right, as far as the level of the aortic arch. The first three thoracic vertebrae also showed small areas of bone destruction. Irregularity of the discs extended as far as the ninth thoracic vertebra. A small area with sclerotic changes, just lateral to the left sacro-iliac joint, was also noted. The chest roentgenogram showed a narrow zone of fibrotic scarring, which radiated laterally from the right hilum to the paraspinal abscess. No active infiltration was noted. Intravenous urography was negative.

In view of these findings, and after consultation with Leo Mayer, M.D., George G. Ornstein, M.D., and George F. Hoch, M.D., spinal fusion was advised. The patient was given penicillin and transfusions of whole blood.

On October 21, 1944, a fusion of the left hemispine, from the occiput to the first thoracic vertebra, was performed. On January 22, 1945, the left hemispine fusion was completed from the seventh cervical vertebra to the tenth thoracic vertebra. There was no postoperative reaction on either occasion. Between spinal operations, penicillin and transfusions were continued, as indicated. A small sinus developed, just inferior to the original one. Incision along the posterior margin of the right sternocleidomastoideus was done on

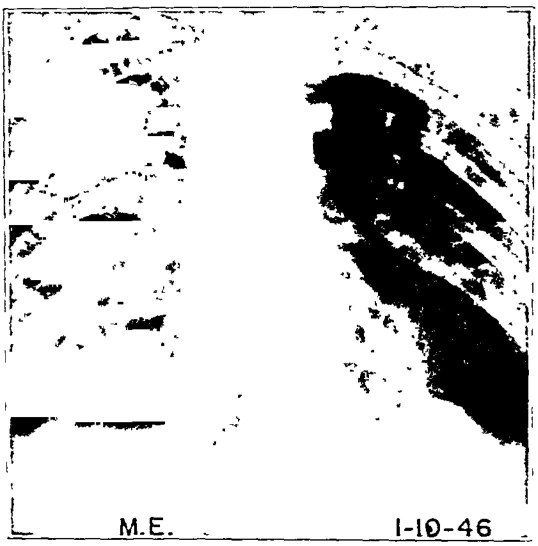

FIG. 3-C

Roentgenograms on January 10, 1946, show clearing of lung shadow and absence of abscess shadow.

TABLE I

PATIENT'S RESPONSE AFTER INSTITUTION OF STREPTOMYCIN THERAPY

Temperature		Sedimentation Rate		Leukocytosis		
Days	Degrees	Days	Millimeters per Hour	Days	White Blood Cells	Percentage of Polymorphonuclear Cells
-1*	101.0	0**	77	-1*	17,150	91
0**	100.6	12	58	10	12,100	82
1	100.6	25	47	12	9,800	82
2	102.4	33	40	26	6,000	77
3	101.2	40	37	33	5,000	73
5	100.6	53	33	53	6,500	62
7	99.2	62	24			
9	98.6	73	12			

* Days prior to administration of streptomycin.
** Day streptomycin was started.

December 26, 1944, in an attempt to divert the drainage away from the carotid sheath. Solid fusion occurred from the occiput to the tenth thoracic vertebra, inclusive (Figs. 2-A, 2-B, and 2-C).

Intramuscular penicillin was continued for nine and one-half months, without healing of the sinuses or regression of the mediastinal abscess. It was discontinued after 32,000,000 units had been injected. The sinuses were then irrigated with penicillin, but the intrathoracic abscess could not be reached by catheter or fluid, because of the obstruction offered by the subclavian vessels. In spite of this treatment and repeated transfusions, the poor general trend continued.

By September 1945, the patient was in an emaciated condition with marked leukocytosis, moderate anaemia, a markedly elevated sedimentation rate, and massive weight loss. On the evening of September 5, 1945, disaster occurred. The paramediastinal abscess ruptured through the pleura and lung into the bronchial tree. The lung was sprayed with the purulent discharge from the abscess.

The administration of streptomycin was started less than twenty-four hours after this episode. The patient received 4,000,000 units during the first twenty-four hours, and the dosage was then maintained at 1,000,000 units per day for fifty days,—a total of 51,000,000 units.

At the end of that time the patient showed marked improvement. His general condition had changed from a desperate state to one of recovery. The sinuses, which had been open for a period of thirteen months, closed in twenty-one days. The temperature went up after rupture of the abscess (Table I), but rapidly subsided to within normal limits, where it remained throughout the rest of the hospital stay. The sedimentation rate, which had been markedly elevated, fell steadily to within normal limits. The marked leukocytosis, present before rupture, reverted to normal with therapy. The sputum, which had been 0 on the Gaffky scale, became Gaffky V after rupture of the abscess. This, too, rapidly declined to 0 by the seventeenth day. All coughing and raising of sputum had stopped at this time. Serial roentgenograms of the chest reflected the dramatic change (Figs. 3-A, 3-B, and 3-C). A chest roentgenogram, which had been taken on August 8, 1945, showed the dense right paramediastinal abscess and slight scarring in the right upper lobe, but no active infiltration. A roentgenogram on September 7, 1945, two days after the rupture, showed a decrease in the density and size of the abscess, but parenchymal infiltration appeared in the right upper lobe and also in the left lower lobe. The progressive clearing of this infiltration and of the original lesion continued.

EPIPHYSEAL COXA VALGA

Report of Two Cases

BY ALVIS D. FINCH, M.D., AND WILLIAM M. ROBERTS, M.D., GASTONIA, NORTH CAROLINA

From the North Carolina Orthopaedic Hospital, Gastonia

Many articles on epiphyseal coxa vara or slipping of the capital femoral epiphysis in adolescence, with a residual varus deformity, have been published since the latter part of the nineteenth century[1]. Apparently, however, no case of epiphyseal coxa valga in the presence of a morphologically well-formed acetabulum has been reported in the English literature, although Müller in 1926 reported the development of coxa valga with epiphyseal slipping in cases of hypoplastic, flattened, or almost vertical acetabula. The condition is not mentioned in standard orthopaedic textbooks. A study of 100 cases of slipped capital femoral epiphyses, treated at the North Carolina Orthopaedic Hospital since 1921, has disclosed only two patients with a valgus deformity. This apparent rarity of epiphyseal coxa valga warrants the report of these cases.

CASE REPORTS

CASE 1. A. F., a negro girl, aged fourteen years, was admitted to the North Carolina Orthopaedic Hospital on February 22, 1944, with chief complaints of stiffness, restricted motion, and pain in the hips. In the summer of 1940 her father had noticed that the patient limped on the left leg; there was no associated pain. In the fall of 1941 she began limping on the right leg, also. Gradually the disturbance in her gait increased, and, on February 23, 1943, the patient was admitted to Duke Hospital. A summary of the significant findings at Duke Hospital is as follows:

"Five months previous to admission, the patient began to limp on the left leg and complained of pain in the left hip. There was no history of trauma or of other known exciting factor. The pain was dull and aching in character, aggravated by motion and weight-bearing, and relieved by rest; it gradually became more severe. During the past month the patient has hardly been able to get around.

"*Physical Examination*: Temperature 37.4 degrees centigrade, pulse 82, respirations 20, blood pressure 110/70. The patient is a well-developed, well-nourished, large colored female who walks rather slowly, taking short steps, with the legs close together and in moderate external rotation, with a rolling motion of both hips, and a shuffling of both feet. The skin is warm, moist, and elastic, without lesions. The patient has the adult female distribution of hair. Both lower extremities are held in external rotation, and there is considerable limitation of internal rotation, abduction, and flexion. There is no tenderness over either hip to palpation or fist percussion. Except for these findings, the general physical examination is within normal limits.

"*Accessory Clinical Findings*: Hemoglobin 91 per cent., white blood cells 6,050, sedimentation rate (corrected) 10 millimeters per hour. Routine Kahn and Kline tests are negative. Urinalysis is negative. Roentgenographic examination of the pelvis, including both hips, shows the neck of the femur to form an angle with the shaft of 165 degrees, bilaterally. There is marked slipping of both femoral epiphyses.

"On February 27, 1943, the patient was given a general anaesthetic; the hips were readily hyperextended and the extremities were internally rotated about 45 degrees and placed in bilateral long-leg casts, with cross-bar struts which maintained the extremities in internal rotation and abduction of about 30 degrees. She remained in these casts until June 23, 1943. Roentgenograms made at that time revealed no change over her original roentgenograms."

Upon admission to the North Carolina Orthopaedic Hospital, on February 22, 1944, the patient was walking with crutches, but she experienced some difficulty because of restriction of motion in the hips. The right lower extremity was held in a position of about 15 degrees of external rotation, and the left lower extremity in 10 degrees of internal rotation. She was treated conservatively, with traction and bed rest. This, however, did not result in any improvement in the roentgenographic appearance of the hips; in fact, recent roentgenograms indicated the development of progressive degenerative changes. There was marked limitation of motion in the hips in all directions.

The preliminary roentgenogram (Fig. 1-A) of the patient's pelvis and hips, taken February 26, 1943, showed moderate, but marked, slipping of both capital femoral epiphyses; the head was displaced upward, laterally, and anteriorly. A line projected upon the upper margin of the femoral neck transected a third or more of the head of the femur. This was in marked contrast with the usual epiphyseal coxa

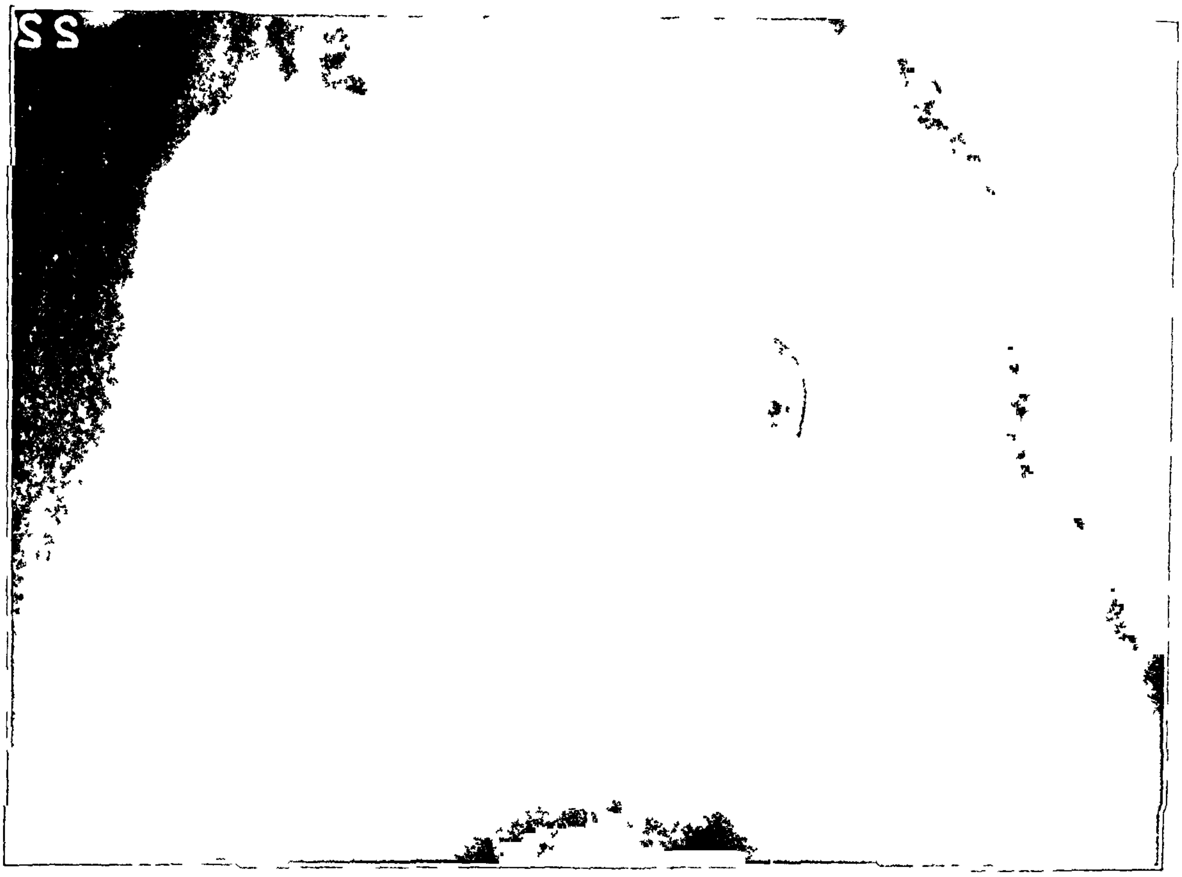

Fig 1-A

Case 1. Roentgenogram taken February 26, 1943, shows slipping of both capital femoral epiphyses

Fig 1-B

Roentgenogram taken April 18, 1946.

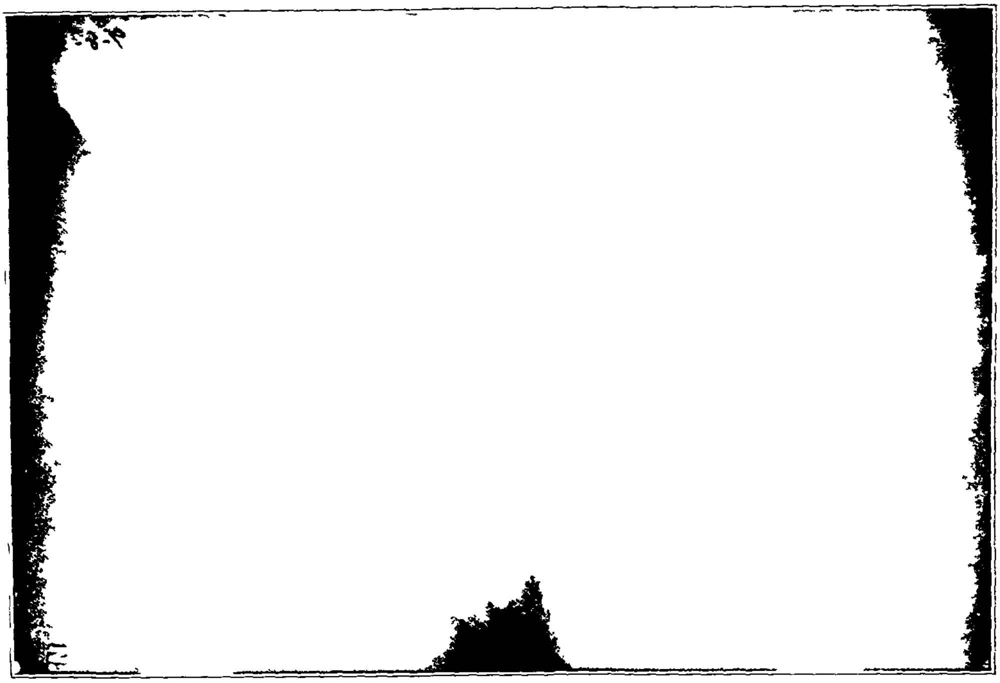

FIG 2-A

Case 2 Roentgenograms taken September 8, 1936, upon admission to the Hospital, show slipping of the heads of both femora

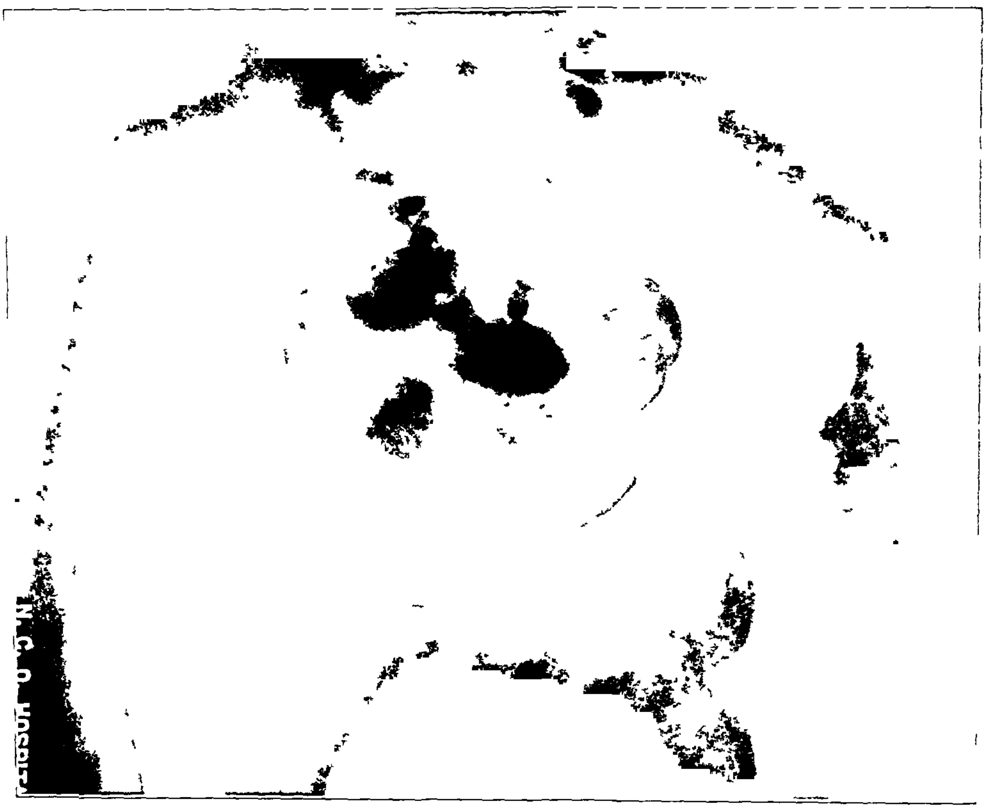

FIG 2-B

Eight months later, the epiphyses have almost closed

vara, in which the head is displaced backward, downward, and medially, and such a line would transect little or none of the head of the femur[3]. Study of the roentgenogram indicated clearly that the coxa valga was not merely an expression of anteversion of the neck of the femur. Unfortunately, lateral views of the hips were not made.

CASE 2. M. H., a lanky negro girl, aged thirteen years, was admitted to the North Carolina Orthopaedic Hospital on September 8, 1936, with a history of pain of insidious onset in the right hip, which began seven weeks before. There was a rather sharp limp of the right hip, considerable spasm of the muscles of the hip and thigh, especially the adductors, and limitation of motion in abduction. The patient had had no trouble whatever with the left hip, in which there was no limitation of motion. The extremities were of equal length. Except for the findings about the right hip, the general physical examination was within normal limits.

A blood examination gave the following results: hemoglobin 84 per cent., red blood cells 4,370,000, white blood cells 8,250. The blood Wassermann was negative. A urinalysis was negative. Roentgenographic examination of the pelvis (Fig. 2-A) showed slipping of the heads of the femora upward, laterally, and anteriorly, although not to such an extent as in Case 1. Unfortunately, lateral roentgenograms of the hips were not taken.

This patient was treated by adhesive traction for a period of eight weeks, and then a right hip spica was applied for an additional six weeks. This resulted in complete relief of the pain and muscle spasm of the right hip, and in considerable improvement in abduction. When last examined, on June 20, 1939, about three years after onset of the first symptoms, the patient walked without any limp and had had no pain for two years. There was no limitation of motion in either hip joint, except for the last few degrees of abduction. The final roentgenograms (Fig. 2-B), taken on May 11, 1937, showed almost complete closure of the capital femoral epiphyses in satisfactory positions, with no evidence of any degenerative changes.

The practical significance of recognition of epiphyseal coxa valga lies in the fact that the use of the conventional, or Whitman, type of reduction by forcible internal rotation is contra-indicated, as it probably increases the displacement of the head of the femur and favors the development of avascular necrosis, as in Case 1.

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UNUSUAL REGENERATION OF BONE IN A CHILD

BY DONALD J. MAGILLIGAN, M.D., BROOKLYN, NEW YORK

There is nothing new about the fact that missing bone fragments can be replaced by spontaneous regeneration. However, the author feels that some of the features of this case make it sufficiently unique to be worth presenting.

The patient, a six-year-old girl of Puerto Rican origin, was brought into Greenpoint Hospital on July 12, 1945. The only history obtainable was that she had been struck by an automobile truck just prior to admission. Her general condition, together with the language difficulty, precluded any other questioning.

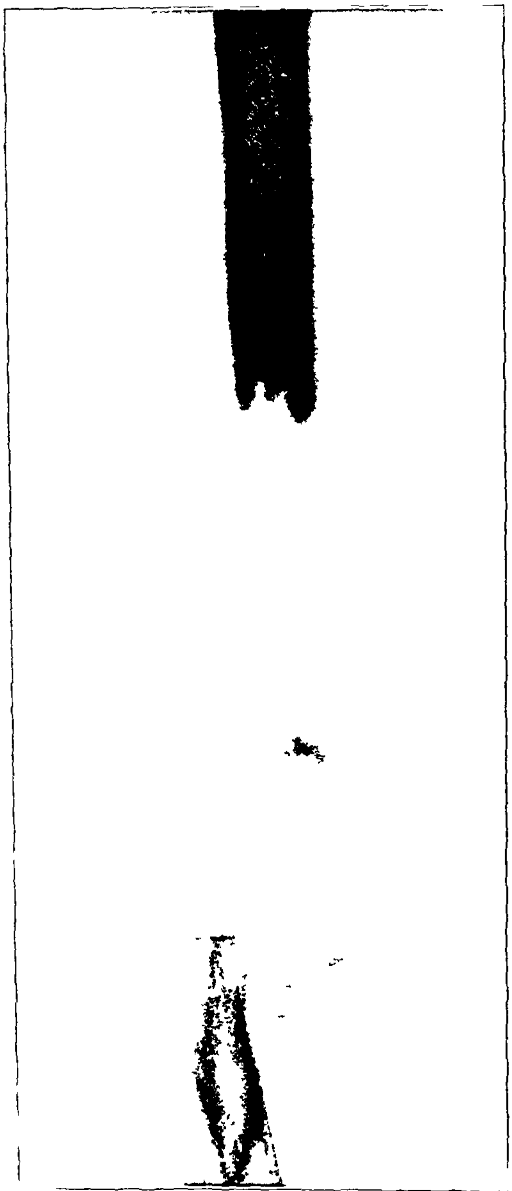

FIG 1

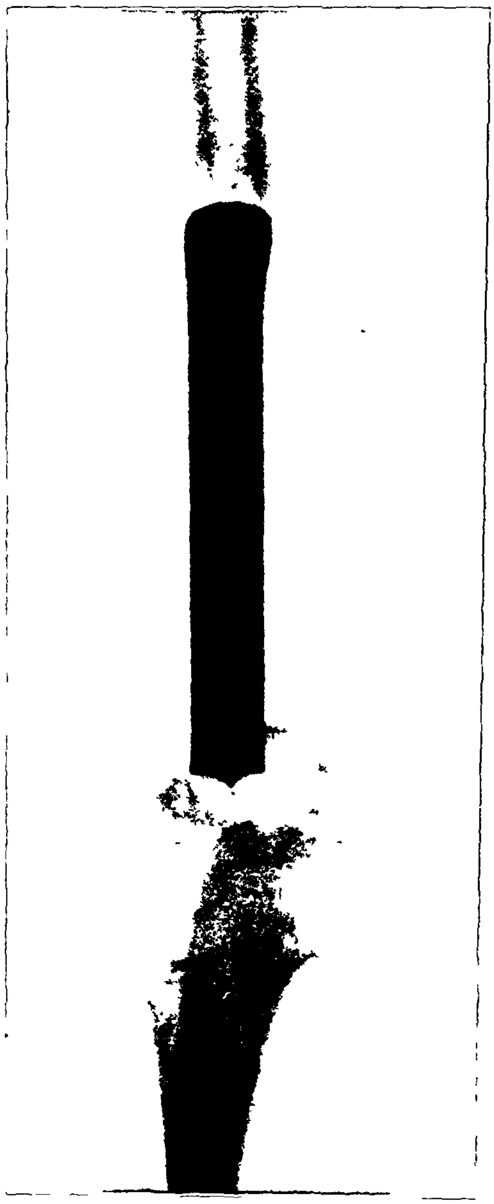

FIG. 2

Fig. 1: Roentgenograms taken immediately after admission to the Hospital.
Fig. 2. The Smith-Petersen nail is demonstrated *in situ*.

Physical examination revealed that the child was conscious, but she did not respond to questions. The only pertinent positive physical findings were confined to the right upper extremity. There were two parallel lacerations, about an inch apart, and each about an inch in length, over the posterior aspect of the humeral condyles. There was markedly excessive mobility of the lower portion of the arm, and moderate bleeding from the lacerations. The forearm showed no external evidence of injury. Finger and wrist motions were normal, and there was no evidence of circulatory disturbance. Sensation was not tested, but there seemed to be no impairment of motor power.

Roentgenograms revealed a comminuted fracture involving both humeral condyles, with one small fragment, apparently free, adjacent to the condyles. The section of the humeral shaft extending from its mid-portion down to the condyles was completely absent; the bones of the forearm were intact (Fig. 1).

Plasma was administered, followed by a mild reaction, with some shock, and the patient passed some blood-tinged urine. Immediate consultation with surgeons and urologist was held, and the consensus was that there were no complicating factors which contra-indicated operation.

It was at first felt that the best way to meet the situation would be to insert a fibular graft into the space left between the fragments. The reasons for this decision were, first, because it was quite obvious that some measures must be taken to maintain the length of the extremity and at the same time to allow a reasonable chance of preventing angulation or torsion deformity; and, second, because it was felt that the fibula presented the most readily accessible source of graft material. The fact was taken into consideration that wounds compounded from within, when treated early and adequately, in general stand a sufficiently favorable chance of healing without infection to justify this apparently radical procedure.

The patient was allowed to recover from shock, but her condition three hours after admission was

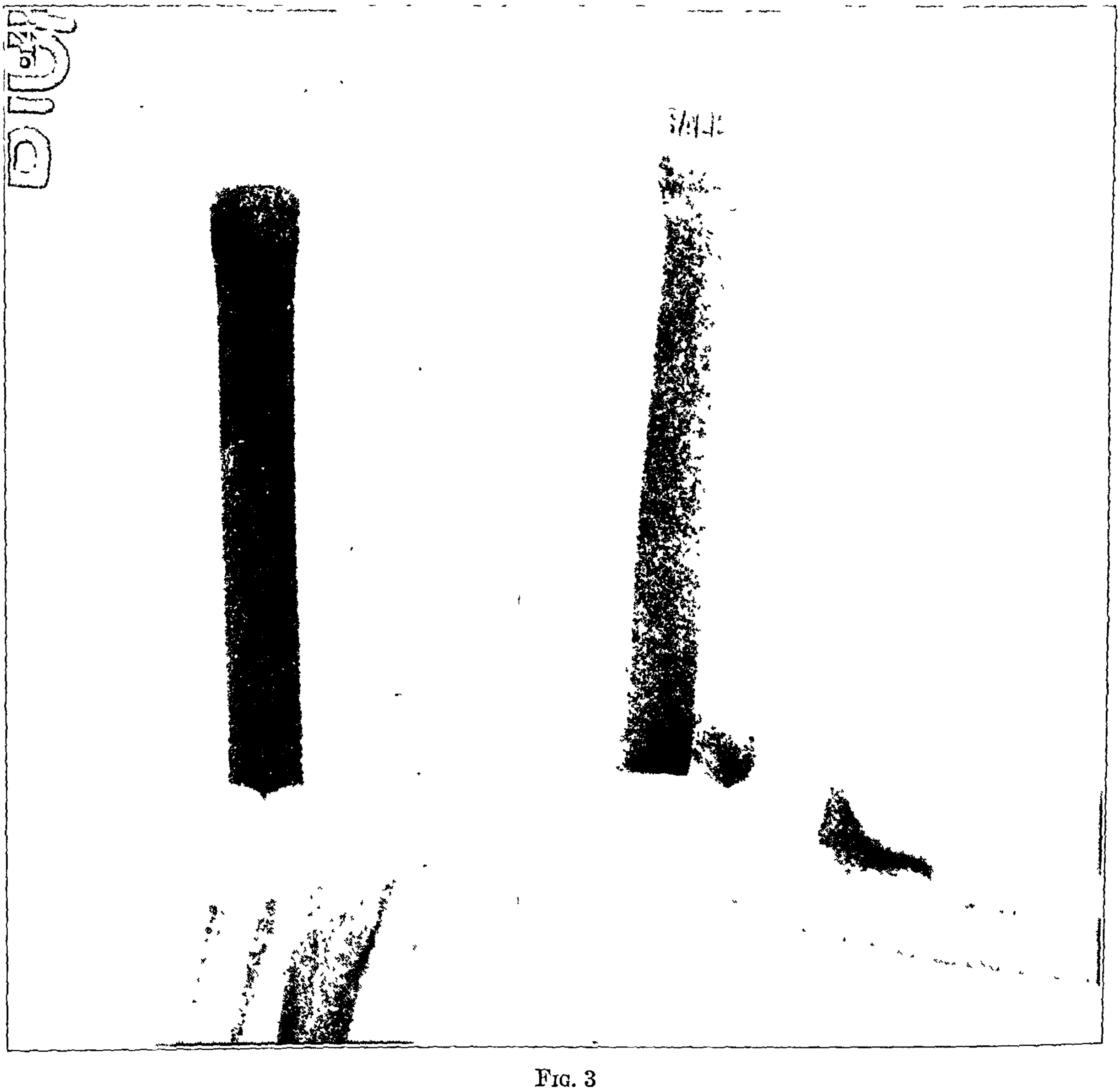

FIG. 3

Approximately three months after operation. There is abundant bone formation, and a pseudarthrosis appears to be forming around the proximal end of the nail.

such as to make it seem unwise to do more surgery than was absolutely necessary; the original plan to take a graft from the fibula was therefore abandoned. The two lacerated wounds were debrided, and were found to communicate with an irregular tear in the lower lateral portion of the triceps and its tendon. Exploration through this tear revealed a perfectly smooth tunnel, leading from the condyles up to the lower end of the proximal fragment. The wall of this tunnel seemed to be intact. As nearly as could be determined by the examining finger, there was absolutely no other soft-tissue injury present.

In the lower part of the tunnel was a small, loose fragment of bone, apparently derived from the condyles (Fig. 1). It was then felt even more strongly that something must be done to keep the walls of the tunnel from collapsing, and to maintain its length, so that later bone-grafting could be done. Several suggestions were made, none of which seemed feasible or wise. Finally, after the idea of using such things as clamps, tissue forceps, or syringe plungers had been discarded, it was suggested that a Smith-Petersen hip nail might serve the purpose. After the previously mentioned loose bone fragment had been removed, a three-and-one-quarter-inch nail was sterilized, and was inserted through the original laceration into the tunnel. The soft tissues were approximated in layers, and the skin lacerations were closed tightly with black silk sutures. The patient was returned to the ward, and the extremity was immediately placed in traction.

Her immediate postoperative course was singularly uneventful, there being only very slight

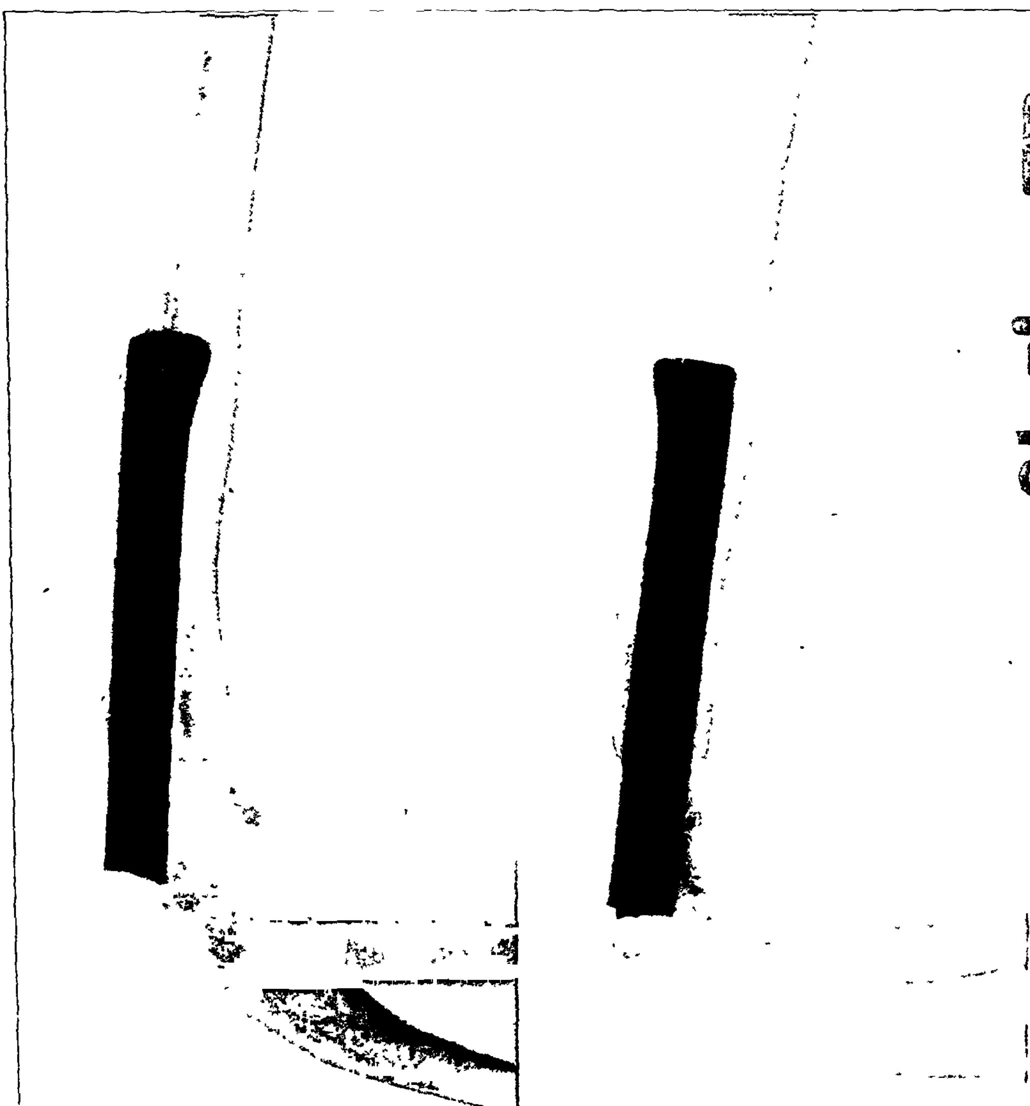

Fig. 4

There is now solid bone formation. The apparent pseudarthrosis has disappeared.

temperature elevation. The forearm, hand, and fingers showed no manifestation of circulatory, nerve, or muscle involvement. It was decided that on July 23 (the eleventh day) the Smith-Petersen nail would be removed, and a bone graft from the leg be inserted. Unfortunately, on the day of operation, a very small quantity of purulent fluid was found in the original wound, and it was thought best to cancel the procedure. A spica cast was applied under anaesthesia, with the elbow at a right angle and the forearm supinated. One roentgenogram, taken nineteen days after the trauma had occurred, showed that a considerable amount of new bone had already been formed; and the idea of removing the nail and substituting a bone graft was then deemed to be impractical and unnecessary. On September 10, the cast was removed, and a posterior molded splint was applied. One week later, the splint was removed, the extremity was placed in a sling, and active motion was started. The patient was kept in the Hospital under observation until November 3, roentgenographic studies being made at intervals.

Since leaving the Hospital, she has been seen only once in the Out-Patient Department, on December 10. Roentgenograms taken on that date (Fig. 4) showed anterior angulation of the distal portion of the humerus. The clinical findings were as follows: The original lacerations had completely healed and were non-adherent. There was a crepitant sensation, just deep to these wounds. There was no deformity. By actual measurement the right arm was one-quarter of an inch shorter than the left. There was no definite atrophy of the arm or forearm. Motion of the right shoulder was complete and painless. Motion of the right elbow ranged from 80 degrees of flexion to 150 degrees in extension; pronation and supination were complete and painless. Motion of the wrist and fingers was complete and painless. There was neither sensory nor motor-nerve disturbance of the extremity, nor was there any alteration in the circulation.

Although the angulation shown in Figure 4 unquestionably had some bearing on the range of motion, it was not otherwise apparent clinically. On palpation, the bony landmarks were in normal relationship to each other, and the carrying angle was normal. Up to that time, there had been no apparent growth disturbance at the lower end of the humerus. Unfortunately, the patient has been lost sight of and cannot be traced; hence it cannot be stated whether or not there has been any subsequent change.

COMMENT

It would appear from this case, in which there was an intact periosteal tunnel and spontaneous regeneration of a segment of humerus, three and one-quarter inches in length, that bone can regenerate from periosteum alone,—at least in children. There was no evidence at any time of irritative or inflammatory reaction at the site of the nail, and the rapid regeneration of the bone bears witness to the fact that vitallium does not inhibit such regeneration.

MARCH FOOT IN A SEVEN-YEAR-OLD CHILD

BY HAROLD M. CHILDRESS, M.D., JAMESTOWN, NEW YORK

The incidence of march fracture of a metatarsal bone, or march foot, was greatly increased during World War II. Civilians as well as military personnel were affected. The occurrence of such a bone lesion in a small child, however, is extremely rare. Only one such instance has been found, after a fairly extensive review of the medical literature. This case, that of a ten-year-old girl, was mentioned by Zeitlin and Odessky[1].

CASE REPORT

R. L. W., a boy, seven years of age (Hospital Register No. 3442), noticed pain on the dorsum of the left foot about one month before admission to the hospital. There was no history of trauma, except that the patient had been walking on a concrete sidewalk one-half mile, three times daily. Discomfort in the foot appeared soon after this activity was started. Two weeks after the onset of pain, a rounded swelling was noted on the dorsum of the foot, which was extremely painful to pressure. The skin over this mass became slightly reddened and was hot to the touch. Rest gave complete relief. The patient remained ambulatory, but the pain became increasingly severe. The condition had been diagnosed by the family physician as an acute infection of the soft tissues.

Physical examination at the time of admission to the hospital disclosed a small, hard, rounded mass over the mid-portion of the second left metatarsal bone. At this time there were no signs of inflammation. Tenderness to localized pressure was moderate The foot musculature and the posture were good. All the other bones and joints were normal.

A urine examination was negative. The blood examination was as follows:

Red blood cells	4,450,000
Hemoglobin	85 per cent.
White blood cells	7,800
Polymorphonuclear neutrophils	47 per cent.
Lymphocytes	50 per cent.
Monocytes	3 per cent.

FIG. 1

Roentgenogram, taken one month after onset of pain, shows typical march fracture in the healing stage.

The roentgenograms (Fig. 1) were interpreted as showing a fusiform area of proliferative periosteal bone, centered about the mid-shaft of the second left metatarsal bone. A thin fracture line was seen in the center of this fusiform mass. The appearance was that of a march fracture or an insufficiency fracture.

The patient was confined to bed for ten days, and then was allowed partial activity for the next three weeks. A low combination longitudinal and metatarsal arch support of sponge rubber was placed in the left shoe. When this patient was last seen, three months after onset, the mass had decreased in size; the pressure tenderness had disappeared; and he was able to walk normally without discomfort.

Had this patient been examined during the acute stage, a diagnosis might have been made of osteomyelitis or even of osteogenic sarcoma. March fracture always should be considered in osteoblastic lesions of the metatarsal bones, even in young children.

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Education Section

FUTURE DEVELOPMENT OF POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY*

BY RALPH K. GHORMLEY, M.D., ROCHESTER, MINNESOTA

The Joint Committee on Postgraduate Training in Orthopaedic Surgery asked your Program Committee for time to present some of the problems that are before us, in the hope that a frank discussion might be provoked. We feel that The American Orthopaedic Association should be, and is, more interested in these problems than any other group. We hope that some suggestions may come from you which will help us to make further plans for the training of orthopaedic surgeons in this country.

In the past year we have tried to keep you informed of some of our activities. An account of the present status of the work of the Committee and of what is left for immediate accomplishment will be presented by the Secretary, Dr. Shands.

How well we are going to train persons seeking to be orthopaedic surgeons is a question that should be given considerable thought by every member of this Association.

PROBLEMS IN DEVELOPMENT OF A TEACHING PROGRAM

A carefully planned, but rapid, increase in the number of resident training programs throughout the country has been made. How well some of these will stand the test of time and experience remains to be seen. Training programs will have to be evaluated carefully and, unfortunately, some may have to be abandoned. Already we find, much to our regret, that some of the residencies, approved after much discussion and correspondence, are not functioning. Such disappointments are bound to come. The Committee has tried to direct the development of residencies in places where it seemed that sufficient material and personnel existed to justify a training program. The stumbling blocks in some places seem to be as follows: (1) administrative difficulties, in particular, where the personnel of two or more hospitals have to work together; (2) the regrettable, but apparently universal, inability of human beings to avoid friction; and (3) the fact that the main interests of many orthopaedic surgeons are in directions other than graduate medical training.

The difficulties of administration usually can be worked out satisfactorily by administrative officials who are interested in developing a program of graduate training. These problems vary greatly from place to place and no one solution can be found for all. The second and third problems are those of individuals, and can be solved only if the development of orthopaedic surgery becomes of such absorbing interest that characteristics which lie at the bottom of imperfect human nature are surmounted. In most instances, however, the development of a well-run residency and the training of a group of able orthopaedic surgeons will do much to enhance the reputation of the chief of service in his community, and will bring to him a lasting feeling of satisfaction.

PROBLEMS OF REVIEW OF, AND TRAINING IN, THE BASIC MEDICAL SCIENCES

The recent emphasis on furnishing an opportunity for residents to review and to advance their knowledge of the basic medical sciences has been the source of some discussion and confusion, and may have held up development of the program in some communities. It is not my purpose to present this problem in detail, but it must be pointed out that, in general, the need for this phase of training has been widely recognized, and today many types of special training in the basic sciences are included in programs for training residents. What method of presentation of these subjects will prove to be best remains to be seen, but out of the many plans should come some improved methods.

Orthopaedic surgeons, like physicians in all other specialties, have come to realize that they cannot develop their specialty to the exclusion of all else, and that it is necessary that they keep informed of the many fundamental developments in general medicine and surgery. Therefore, the program must be directed toward a better and broader training of the specialist.

The day may not be far distant when a uniform examination in the basic sciences must be passed by a candidate before he can begin training in a specialty. To me it seems that it would be a mistake to institute such a procedure, but it is a plan seriously contemplated by the specialty boards at this time.

* Read before the meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 28, 1946.

PROBLEMS OF TRAINING IN ORTHOPAEDIC SURGERY

Dr. Frank Dickson, in his Presidential Address before this Association in 1940, said: "There is a responsibility which rests upon the members of the American Orthopaedic Association that I doubt has been appreciated in its true importance. I refer to the obligation which rests upon each of us to provide satisfactory training to the extent of his ability for those who wish to enter the field of orthopaedic surgery. . . . There must be, in addition, a willingness to coordinate these one-year and two-year training opportunities with others, so that an acceptable three-year period of training may be available for every applicant for Board certification who is deserving of such training. It is possible that you may be called upon in the near future to cooperate with the American Board to this end."

Because of the recognized scope of orthopaedic surgery, training in this specialty must cover three phases. This is recognized by all, and no further emphasis is necessary. To cover all three phases of the training in one institution is oftentimes impossible. The development of separate hospitals for the care of crippled children has been a notable trend in the past quarter of a century. It seems possible now that this separation may have been overemphasized. However, the principal problem in this phase is to utilize to the utmost, in the training of orthopaedic surgeons, the existing services for treatment of crippled children. Three questions must be answered concerning this problem:

1. Is there enough orthopaedic surgery among children to allow adequate training in this department of the specialty for those who ask for qualification therein?
2. Is one year of training in orthopaedic surgery, as applied to children, sufficient to qualify a man to do this work?
3. Will economic and political trends further reduce the amount of orthopaedic surgery among children which is now available in institutions approved for residency?

Because of the relative scarcity of orthopaedic services on which the patients are children, the Committee urges that all such services which are available be used for training purposes when it is possible to do so.

Many problems relating to the adult phase of orthopaedic surgery remain to be solved. The scope is large and, while orthopaedic surgeons cannot take care of every patient whose complaints might come under this heading, it is their responsibility to point the way toward newer and better methods of diagnosis and treatment of orthopaedic conditions and to assume leadership in the teaching of these methods.

To anyone who has watched the trends during the past quarter of a century, the shift of responsibility for the care of fractures and of teaching concerning this care from the general surgeon to the orthopaedic surgeon is obvious. This is no doubt due to the fact that the orthopaedic surgeon has shown more interest and ability to carry out this task. Many patients have come to regard the orthopaedic surgeon as the specialist to be consulted in the care of difficult fractures. Most of the service men from World War II who were cared for in General Hospitals learned to regard the orthopaedic surgeon as the man who cared for injuries of the extremities, as well as amputations and most aches and pains in the extremities.

Certain professors of surgery are loath to permit orthopaedic surgeons to assume the care of fractures or the instruction of students concerning fractures. They explain their attitude by pointing out that it is their responsibility to train general surgeons and that, of course, part of the training must be in the care of fractures. This attitude is not justified in institutions where orthopaedic surgeons are well versed in the care of fractures, and anxious to help with that phase of teaching. Continued effort on the part of all orthopaedic surgeons to demonstrate ability in the care of fractures and to improve methods of teaching will result in more services coming under the care of orthopaedic surgeons.

COMMENT

Are we to continue to supply and to supervise the training of men to carry practice in the specialty to better and higher levels of accomplishment? Now is the time to realize the position of orthopaedic surgery. It has developed rapidly and has made great strides. With the help of the young men who are becoming orthopaedic surgeons, the specialty should go forward to greater and better things.

A number of affiliations between training services have been developed. The Committee has not felt that it should designate services for affiliation, although suggestions have been made in some instances. We feel that more lasting affiliations will be made through mutual selection by chiefs of services. If, in any instance, the Committee can help in the selection of affiliates, it will be glad to do so.

It is not, and never has been, our purpose to attempt standardization of teaching services. Some minimum requirements have been established and will be a guide to many. As time goes by and experience is gained, a greater tendency to standardization may develop, particularly if some services seem to develop a consistently better type of orthopaedic surgeon than others. The following factors seem to be important in a good teaching service: (1) willingness of orthopaedic surgeons to devote time

to teaching, (2) ability of such personnel to teach, (3) amount and variety of clinical material, both in the hospital and in out-patient departments, (4) availability of laboratories, postmortem service, pathological demonstrations, library and motion-picture films, (5) the possibility of conferences and seminars, (6) contacts with men on other services, both teachers and students, with exchange of ideas about current medical topics, and (7) frequency of contact with visiting surgeons and lecturers.

In order to present examples of some of the organized teaching services for training orthopaedic surgeons, I have asked that several of the plans for training be submitted. These plans are diversified and often complex.

To those who have visited the British Isles, the position of British orthopaedic surgeons in the scheme of specialization has seemed more advanced and secure than our own. They have been recognized more widely than American orthopaedic surgeons have been. During World War I, due to the magnificent leadership of Sir Robert Jones, the specialty became well founded and well recognized and, in turn, it has contributed much to the advancement of medical science.

One of the distinguished leaders of British orthopaedic surgery, Mr. Harry Platt, is a guest at this Meeting. That his group is contributing to the development of this specialty is manifested by two articles written by him, which have appeared in British medical literature in the past two years. These deal with "Orthopaedic Surgery and the Future" and "The Place of Orthopaedics in Medical Education". Both of these articles are worth perusal and study.

Our Committee looks upon the development of a postgraduate training program as a never-ending task. The ultimate goal—a group of perfect orthopaedic surgeons—will, of course, never be reached. One of the most fascinating features of the practice of medicine is the constantly changing viewpoint. New methods are devised, only to be superseded and outmoded by newer methods. Orthopaedic surgery is among the advancing phases of medical science and, if its practitioners are alert, its progress cannot be stopped. We want every member of this Association to feel it his duty to help develop better training for orthopaedic surgeons.

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DISCUSSION

Dr. Guy A. Caldwell, New Orleans, Louisiana: The report of Dr. Ghormley, covering the excellent contribution made by his Committee to meet a veritable crisis in the progress of orthopaedic surgery, is excellent and requires only commendation, rather than comment. The Joint Committee on Postgraduate Training has worked closely with the Council on Medical Education and Hospitals and with the Committee on Resident Training from The American Board of Orthopaedic Surgery.

Additional residencies for training in orthopaedic surgery must be made to conform with requirements of the Council on Medical Education and Hospitals of the American Medical Association, because the Council is t' e only organization which has authority to approve resident training programs in hospitals. Many hospitals seeking to have orthopaedic services approved for resident training are required to submit a formal application to the Council. The Council then sends a representative to the hospital to make a detailed survey, the report of which is submitted to the Council and to the Board's Committee on Resident Training. The latter Committee can review the report and make recommendations, but final approval of any training service rests with the Council on Medical Education.

The American Board of Orthopaedic Surgery was incorporated in 1934 and received official approval by the Advisory Board of Medical Specialties and the Council on Medical Education and Hospitals. Its stated purposes, as set forth in its charter, are, first, "to elevate the standard of qualifications for the practice of orthopaedic surgery and to certify those surgeons who voluntarily comply with its requirements" and, second, under Article 2, Section 2, "to test and determine the qualifications of applicants for examination and to issue certificates to those found qualified".

The Board is composed of nine members, elected by three component organizations,—namely, the Orthopaedic Section of the American Medical Association, The American Orthopaedic Association, and The American Academy of Orthopaedic Surgeons. The American Orthopaedic Association is represented by three members on the Board,—namely, Dr. LeRoy C. Abbott, Dr. Fremont A. Chandler, and Dr. Allen F. Voshell. Members are elected for a term of three years and no one member may succeed himself for more than three terms, or a total of nine years. It is evident from these facts that the nine Board members, representing the three component organizations, are obligated to carry out the stated purposes in conformance with the terms of its charter and the rulings of the Council on Medical Education.

In 1934, the Board set about its task by having those who then were practising orthopaedic surgery

submit their qualifications and references for review by a Committee on Eligibility. No standards of training having previously been established, this Committee necessarily used great latitude and discretion in review of the data submitted. The training and experience of most of the applicants were "irregular", as judged by present standards, but whenever an applicant was found to have acquired adequate experience in the specialty *by any means whatever* and was found to be limiting his practice to orthopaedic surgery, it was ruled that he was eligible for examination. Examinations were given with consideration and discretion, those of the earlier groups who passed the examinations were certified, and thus the work was begun.

However, to meet the obligation of raising the standards of orthopaedic surgery, the Board made certain rulings and announced certain intentions. It stated that thereafter an applicant must show that he had had *three years of intensive training in orthopaedic surgery*, at least *two* of which had been spent as resident on an orthopaedic service in an accredited hospital. Furthermore, it was announced in the rulings that, after 1938, three full years of resident training would be required. Therefore, an adequate interval of time from 1935 to 1938 was allowed to enable all who were practising orthopaedic surgery, but who had received irregular training, to make application and take the examinations. At the same time hospitals, trainees, and diplomates interested in advising their assistants were notified that, after 1938, three years of training on orthopaedic services accredited by the Council on Medical Education and Hospitals would be required.

Early in its career, the Board's experience with applicants indicated that *in general*, training acquired by preceptorship or apprenticeship was inferior to resident training on accredited services. Such training was, therefore, discouraged and penalized in the interest of raised standards. The following ruling was made: "Preceptorship: In certain instances the Board may recognize training under the preceptorship system. Applicants under this category must show evidence of having received a rotating internship and at least one year of surgical training in an approved hospital, must have served for a period of at least five years as a full-time assistant to an orthopaedic surgeon certified by the Board and, in addition, must have been engaged in practice limited to orthopaedic surgery for a further period of five years. During this latter period he should have held a position on the staff of an approved hospital as orthopaedic surgeon and should have given evidence of scientific and professional ability."

From 1936 until 1944, there were only the two approved plans for training: (1) three years of orthopaedic resident training on services approved by the Council on Medical Education and Hospitals, and (2) the preceptorship plan, requiring the lapse of at least twelve years after graduation from medical school.

In 1944, after much consideration, the Board approved a third plan of training, designated as "Combined Assistantship and Resident Training". This was done because Board members recognized that, in certain cities where medical schools and approved resident-training services do not exist, diplomates have organized large private clinics and services in community hospitals which offer excellent opportunities for training for limited periods of time and have the advantage of placing the trainee in contact with private patients. Nevertheless, it was recognized from the outset that the number of such positions would be limited and that such services must be carefully reviewed by the Board itself, since the Council on Medical Education could not take cognizance of such services. On the whole, the plan is regarded by the Board as experimental and may prove to be impractical. Nevertheless, it is presently acceptable when it conforms to the following ruling: "In special instances with the approval of the Committee on Resident Training the Board will recognize for not over two years' training in orthopaedic surgery periods of training in which the candidate combines work in a hospital service with part-time assistantship to an orthopaedic surgeon certified by The American Board of Orthopaedic Surgery, provided that the major part of his time is spent by the candidate in the hospital service". Please note that credit for such service cannot be extended except when the applicant and the diplomate concerned submit *beforehand* to the Committee on Resident Training a prospectus, showing the plan of service and the amount and variety of clinical material available to the trainee in the course of his service.

With the outbreak of World War II and the mobilization of hundreds of orthopaedic surgeons and trainees into the Armed Forces, the question was raised as to credits that might be allowed for experience gained while in the Service. The Board, therefore, ruled as follows: "During the recent national emergency, credits up to a maximum of two years may be allowed for experience gained in surgery and orthopaedics while serving with the Armed Forces. Credits will be given only upon presentation of evidence that such service has, in the opinion of the Committee on Eligibility, been equivalent to similar periods of approved hospital training. Record of all such military service should be kept in the Record of Professional Assignments prescribed by the Advisory Board for Medical Specialties and submitted with his application.

"(a) A year of orthopaedic experience with the Armed Forces may be accepted to replace one of the three required years of orthopaedic resident training."

In general, the Committee on Eligibility approves such credit only when the Record of Professional Assignments shows that the trainee served for as much as a year upon an orthopaedic service in a General

Hospital under supervision of a diplomate of the Board. Because the work on such services was largely limited to fractures and other orthopaedic problems common to young adult males, the year of credit must apply to the required six months of fracture training and six months on the required year of adult orthopaedic surgery.

"(b) A second year of orthopaedic service with the Armed Forces may be credited as a year toward the practice requirement." This credit on the practice requirement is, in general, allowed to all applicants who served with the Armed Forces, regardless of the character of their service.

Although it obviously was essential that the Board recognize the problem of the trainees whose resident training was interrupted by the necessity for entering Military Service, and grant such credits as might be possible, it was equally important not to lower the standards of orthopaedic surgery. To have lowered these standards would be unfair to diplomates who had gone before and equally unfair to those who would come after the War. Nevertheless, the problem of evaluating orthopaedic training received while with the Armed Forces, and of advising the hundreds of young men whose training had been interrupted as to the character of service needed to complete their training, has greatly complicated the duties of the Secretary of the Board, the Committee on Eligibility, and the Secretary of the Joint Committee on Postgraduate Training.

In 1942, the Board divided the examination into two parts: The minimum requirements for Part I of the examination "shall consist of completion of a rotating internship followed by at least one year of resident training in orthopaedic surgery on an approved service".

For Part II: "Candidates applying for examination, Part II, must have successfully passed Part I and must have completed the prescribed training and practice periods, as defined in Article 7, Section 2".

The purposes for making this change were:

1. To screen prospective candidates for Part II early in their training, before they had invested five years' time and much money in the required training and practice periods;
2. To bring trainees in contact with the Board and its rulings early in their training, so as to guide them in selecting services for completion of their training;
3. To enable trainees whose training was interrupted by Military Service to complete their examinations in the Basic Sciences and Surgical Principles before they were too long separated from their medical school and hospital training;
4. To assist military authorities in the selection of men for orthopaedic services.

The plan was put into effect in 1943. It is a definite departure from the examination procedures used by other specialty boards; it adds greatly to the work of the Board, its officers and committees; and it multiplies the expense. Nevertheless, after three years of experience with the plan, the Board Members are unanimous in their approval. The plan has not only accomplished the four purposes mentioned, but, because Part I of the examinations has been given each year in four different centers with the assistance of many of our teachers and diplomates who would otherwise not be concerned with Board activities, it has awakened deep interest in, and support for, the work of the Board throughout the country.

From the time the Board was incorporated, it was recognized that well-rounded training in orthopaedic surgery should include instruction in the basic sciences (anatomy, pathology, physiology, and biochemistry) and in the three phases of orthopaedic surgery,—namely, those concerned with children, adults, and fractures. As time went on, it became apparent that many applicants were receiving poorly balanced training, either because the material in some of the approved three-year training centers was inadequate in some of the phases, or because the applicants took part of their work in one institution and part in another and skipped some of the essentials to well-rounded training, although they had spent the required three years on approved resident training services. In 1943, this problem was discussed with representatives of the Council on Medical Education and with their counsel; the total three-year program was defined to include one year of children's orthopaedics, one year of adult orthopaedics, six months of fractures, and six months of basic-science training. As stated in the ruling: "All of this work may be carried on concurrently" [in a hospital with an approved three-year training program]. "In many instances, however, the applicant may take each phase of this training in a different institution."

By defining the four phases of orthopaedic training thus, many of the three-year training services have improved and balanced their work, and many institutions have been able to set up approved training in one or more phases, thus making it possible to affiliate groups of special hospital services or to provide opportunities for matched training in different institutions, that will meet the requirements. During the present crisis, when it has been necessary for the Joint Committee on Postgraduate Training to expand the number of approved services rapidly, this foresighted ruling passed by the Board and Council in 1943 has been of great assistance.

During the years 1943, 1944, and 1945, the officers of all the Surgical Specialty Boards met repeatedly to confer upon measures to improve resident training. There was unanimous recognition of two weak points in all the Surgical Specialty programs: (1) failure in all but the better university-controlled programs to provide adequate instruction in the basic sciences, as related to the various specialties, and

(2) a tendency to permit trainees to launch out into specialty training without first being well grounded in surgical principles.

When the Boards, acting through the Council on Medical Education and Hospitals, began to request the hospitals and medical schools to allow more time for instruction in the basic sciences and more assistance in teaching, they received numerous inquiries and requests from medical schools and hospitals to specify approximately the period of time that should be given to such instruction and to specify a general pattern for such training. In an effort to comply with these requests, our Board defined its basic-science requirement and specified a general pattern for its teaching. This is not intended to be an absolute and fixed schedule,—especially not in the three-year training centers in which the basic-science training may better be integrated throughout the entire period. However, it has been and will be a real help to those who must try to obtain a complete, well-rounded training by matching the services of several institutions. Those associated with university-controlled programs, who are prone to criticize this and some similar rulings of the Board as being too specific and formalized, must be reminded that probably less than half of the candidates applying for examination and certification by the Board are trained in three-year centers.

In these few minutes I have tried to cover briefly the major steps in the evolution of the Board as it has struggled during the changing times to carry out the purposes for which it was created,—namely, "to raise the qualifications and standards for the practice of orthopaedic surgery and to certify those surgeons who voluntarily comply with its requirements".

During my term of office as Secretary, many complaints have been registered against the rulings of the Board and their interpretation by the various committees. In some instances, these have been justified and have been corrected as promptly as possible. Most complaints, however, have arisen from lack of familiarity with the rulings,—both by candidates and by our own diplomates. The saddest instances of candidates rejected for lack of proper training have arisen because they were ill-advised in the planning of their training by diplomates of the Board, who seem to think it unnecessary to familiarize themselves with the revised rulings issued from time to time. Their advice to candidates of today has been based upon their experience with the Board when they were examined, ten years ago. Others have been advised on the basis of the diplomates' conception of what should constitute good training, rather than on present rulings of the Council on Medical Education and the Board. The next most frequent criticism has been that the Board is *too rigid* and literal in the application of its rulings; but, curiously enough, there is another considerable group who complain that the regulations and requirements are enforced with too great leniency. The latter group would use a standard measuring rod and give an unqualified "yes" or "no". The former would eliminate all prescribed training, do away with the Committee on Eligibility, and invite all who claim to have had training to take the examinations, thus relying entirely upon a single examination to determine the standards of orthopaedic surgery in America.

In conclusion, I would like to urge the following points:

1. Let every diplomate of the Board review carefully the revised rulings.
2. Let us suggest to every prospective candidate, who wishes advice concerning his training, to write to the Office of Orthopaedic Information or to the Secretary of the Board.
3. Let us realize that better orthopaedic surgeons will be developed when the standards of resident training are maintained at a high level. This can best be accomplished through the efforts of this Joint Committee to keep in close touch with all training services. This Committee, therefore, must have the wholehearted support of every member of the Association.
4. Whenever and wherever you hear a diplomate of the Board criticizing its policies and rulings, please make note of his name and nominate him for membership on the Board. Three years of struggling with its problems will cure the complaints of its severest critics!

REPORT FROM THE COMMITTEE ON POSTGRADUATE TRAINING IN ORTHOPAEDIC SURGERY AND THE OFFICE OF ORTHOPAEDIC INFORMATION

Since the last report of the Committee on Postgraduate Training and Office of Orthopaedic Information in the July issue of *The Journal,* the work of this Committee and Office has continued to be most active. As of August 15, there were on file 294 names of medical veterans who were desirous of obtaining orthopaedic training in 1946. However, because much of the information on these veterans was several months old, it was believed that many of this number have now either changed their plans for training or have received appointments, and that this Office was not notified. A questionnaire was sent out on August 17 to determine the present status of this group. As of September 6, 213 replies have been received. The analysis of the information on the questionnaires returned shows that the situation for orthopaedic training in 1946 is not so acute as it was several months ago. Of the 213 men who replied, ninety-nine, or 46 per cent, are still desirous of orthopaedic appointments for 1946; forty, or 18

per cent., for 1947; twenty-three, or 11 per cent., for 1948. Twenty-five, or 11 per cent., now have appointments, but will require further training to complete the requirements of the Board; and twenty-six, or 12 per cent., are either completing their training at the present time or have gone into general practice. It is likely that most of the eighty-one whose questionnaires have not been returned are also in this latter group.

The questionnaires indicate that the majority of those not placed would definitely be interested in a combined assistantship and resident training, as stated in Section II, Paragraph 3, in the Information Bulletin published by The American Board of Orthopaedic Surgery, revised in January 1946.

Since the last report, there has been no change in the total number of approved residencies, this number being approximately 450; but there are at the present time about ten additional hospitals, with approximately fifteen residencies, that are in the process of being approved by the Board and the Council on Medical Education and Hospitals of the American Medical Association. The Board has stated that, if a hospital has been approved for resident training, the decision will be left to the hospital regarding the number of residents they wish to train. This will enable many of the hospitals to train additional men without further approval.

Since the last report, this Office has been notified of only five vacancies. There are, however, still being established new resident training services in the Veterans Hospitals, which will have many new appointments to make. From the information this Office has had, some of these Veterans Hospital services are going to afford excellent training for the residents. Many Veterans Hospitals now have full-time Board Diplomates as chiefs of service.

The Office continues to receive requests for the names of fully trained orthopaedic surgeons to fill permanent locations. The Secretary will greatly appreciate hearing from men who have taken their full training and wish locations for practice.

FOR THE COMMITTEE ON POSTGRADUATE
TRAINING IN ORTHOPAEDIC SURGERY
A. R. Shands, Jr., M.D., Secretary

THE INTER-AMERICAN ORTHOPAEDIC FELLOWSHIP PROGRAM

The Committee on Inter-American Fellowships in Orthopaedic Surgery, representing The American Orthopaedic Association and The American Academy of Orthopaedic Surgeons, has been forced to discontinue its fellowship program for the present, because of overcrowded conditions in American teaching centers.

During the three years in which this fellowship program was operating, eighteen Latin American students of orthopaedic surgery spent from six months to two years in various teaching centers in the United States. The whole experience was most beneficial from the standpoints of both the students and the faculties involved.

The funds for support of this orthopaedic fellowship program were generously provided by the W. K. Kellogg Foundation of Battle Creek, Michigan. In addition to a monthly stipend, each student's expenses were paid while he attended an annual meeting of The American Academy of Orthopaedic Surgeons. At the end of his period of training, each fellow was accorded a travel period of a month on an itinerary of his own selection.

While in the United States this group of students organized an Orthopaedic Correspondence Club, which they expect to continue after returning home and which should prove to be of distinct professional and social value to them and to their respective communities.

Such a sponsored fellowship program has the wholehearted endorsement of the Department of State. Undoubtedly it is of value in giving concerted guidance to the visiting students of orthopaedic surgery. It is unfortunate that the program must be curtailed, even temporarily, as many applications have had to be rejected from foreign students hopeful of such an opportunity.

Oscar Lee Miller, M.D., Chairman

News Notes

The Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held at the Palmer House, Chicago, from January 25 through 31, 1947. It is expected that the guest speaker will be Sir Reginald Watson-Jones. The Instructional Courses, under the Chairmanship of Dr. Walter P. Blount, will be given on January 25 and 26. Further information may be obtained from the Secretary, Dr. Myron O. Henry, 401 Medical Arts Building, Minneapolis, Minnesota.

The **Atlas of Orthopedic Pathology** was prepared in 1943, at the Army Medical Museum, by Major D. M. Angevine and Colonel J. E. Ash, from material in The Registry of Orthopaedic Pathology. Its publication was sponsored by The American Academy of Orthopaedic Surgeons and The American Board of Orthopaedic Surgery. Copies are still available, and may be purchased from Dr. Joseph A. Freiberg, 707 Race Street, Cincinnati 2, Ohio. The price is $5.00 per copy, and remittance should be ent with the request.

Dr. M. N. Smith-Petersen has recently returned to Boston after spending several months in Norway. While there Norway's highest honor, that of Commander of the Royal Order of St. Olav, was bestowed upon Dr. Smith-Petersen by King Haakon.

Dr. J. E. M. Thomson, of Lincoln, Nebraska, who went to Czechoslovakia as a member of the Unitarian Medical Teaching Mission, and other members of the Mission were awarded the highest recognition of the Czechoslovakian Republic,—that of the Order of the White Lion, given by the government for distinguished service. Dr. Thomson was also a guest speaker at the congress of the *Československa Společnost Ortopedicka* held on August 28, 29, and 30, and was elected to honorary membership in the society.

The American Board of Orthopaedic Surgery will hold its next examination (Part II) at Chicago, Illinois, on January 22, 23, and 24, 1947. The deadline for receipt of completed formal applications and application fees is November 1, 1946. Letters of request and applications received after this date cannot be accepted. Correspondence and applications related to Part II of the examination should be sent to the Secretary, Dr. Francis M. McKeever, 1136 West Sixth Street, Los Angeles 14, California.

ARMY INSTITUTE OF PATHOLOGY AND AMERICAN REGISTRY OF PATHOLOGY

What is now known as the Army Institute of Pathology was established in 1863 as the Army Medical Museum. During World War II the activities of the Institute were greatly expanded, especially in the field of diagnostic pathology and research. There are now on file over 170,000 accessions. The results of research at the Institute during the past few years will be published in a volume of about 1400 pages as a part of the official history of World War II.

On request of Major General Norman T. Kirk, The Surgeon General of the Army, the Committee on Pathology of the National Research Council, Division of Medical Sciences, in late 1945 prepared a report on the future development of the Institute. The report has been approved by The Surgeon General and by the War Department.

The essential recommendations in this report are: (1) that a new building of adequate size be constructed; (2) that the Institute be organized in four divisions—Department of Pathology, Army Medical Illustration Service, Army Medical Museum, and American Registry of Pathology—each headed by a competent specialist; (3) that the staff of the Institute be drawn from both the commissioned ranks of the Army and from the civilian professions; (4) that a comprehensive educational and training program be undertaken; (5) that the vast store of material at the Institute be used for research; and (6) that the services in pathology in the Veterans' Hospitals be centralized at the Institute.

The American Registry of Pathology, founded in 1922, thus is, and will continue to be, an integral part of the Army Institute of Pathology. There were, on January 1, 1946, over 43,000 cases registered.

At the present time the American Registry of Pathology comprises fourteen registries. One of these is the Registry of Orthopaedic Pathology, established in 1943 and sponsored by The American Academy of Orthopaedic Surgeons.

All specimens in the Registry are available for review and research by competent investigators. Sets of slides and accompanying syllabuses on special fields are available for loan to the civilian professions and officers in the federal services. Physicians, dentists, and veterinarians are urged to send unusual specimens together with an abstract of the history to the Registry. The contributor receives a report on each specimen and is asked to keep the Registry informed of the follow-up on the patient.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Fifty-Ninth Annual Meeting of The American Orthopaedic Association, under the Presidency of Dr. J. Albert Key, was held at The Homestead, Hot Springs, Virginia, June 27, 28, and 29, 1946. Two symposia were presented and a number of papers were read, as follows:

THURSDAY, JUNE 27

Morning Session

Another Treatment for Congenital Flat Feet.
James E. M. Thomson, M.D., Lincoln, Nebraska (read by J. Warren White, M.D., Greenville, South Carolina).
Discussion: Lenox D. Baker, M.D., Durham, North Carolina (by invitation);
J. Warren White, M.D., Greenville, South Carolina.

The Definition of Human Locomotion on the Basis of Measurement, with Description of Oscillographic Method.
R. Plato Schwartz, M.D., Rochester, New York.
Discussion: Verne T. Inman, M.D., San Francisco, California (by invitation);
Robert W. Johnson, M.D., Baltimore, Maryland;
Arthur Steindler, M.D., Iowa City, Iowa.

Hypermobile Flat Foot with Short Tendo Achillis (HFF-STA).
Robert I. Harris, M.B., Toronto, Ontario, Canada;
Major T. Beath, M.C., Toronto, Ontario, Canada (by invitation).
Discussion: Frank D. Dickson, M.D., Kansas City, Missouri;
Edwin W. Ryerson, M.D., Chicago, Illinois;
John R. Moore, M.D., Philadelphia, Pennsylvania;
John L. McDonald, M.D., Toronto, Ontario, Canada;
J. Warren White, M.D., Greenville, South Carolina;
Compton Riely, M.D., Baltimore, Maryland;
Fremont A. Chandler, M.D., Chicago, Illinois;
Halford Hallock, M.D., New York, N. Y.;
Robert I. Harris, M.B.

Pre-Employment Back Examinations.
Steele F. Stewart, M.D., Honolulu, Hawaii.
Discussion: Philip Lewin, M.D., Chicago, Illinois;
Steele F. Stewart, M.D.

Active Splinting of the Hand.
Sterling Bunnell, M.D., San Francisco, California (by invitation).
Discussion: Philip D. Wilson, M.D., New York, N. Y.;
Sterling Bunnell, M.D.

Evening Session

Symposium on the Intervertebral Disc.
Arthur G. Davis, M.D., Erie, Pennsylvania, *Chairman.*
End-Result Study of the Intervertebral Disc.
Raymond E. Lenhard, M.D., Baltimore, Maryland (by invitation).
Ruptured Intervertebral Disc and Sciatic Pain.
Joseph S. Barr, M.D., Boston, Massachusetts.
The Disc Factor in Low-Back Pain with or without Sciatica.
J. Grafton Love, M.D., Rochester, Minnesota (by invitation).
An Analysis and Differentiation of Low-Back Pain in Relation to the Disc Factor.
Arthur Steindler, M.D., Iowa City, Iowa.
Diagnosis by Myelography in Disc Lesions.
Lt. Colonel Aubrey O. Hampton, M.C., A.U.S. (by invitation).
Pathological Studies on Intervertebral Discs.
Charles Eckert, M.D., St. Louis, Missouri (by invitation);
Alfred Decker, M.D., St. Louis, Missouri (by invitation).
Anatomico-Physiological Aspects of Injuries to the Intervertebral Disc.
Verne T. Inman, M.D., San Francisco, California (by invitation);
J. B. deC. M. Saunders, M.B., San Francisco, California (by invitation).

Discussion: William Jason Mixter, M.D., Boston, Massachusetts (by invitation);
Theodore A. Willis, M.D., Cleveland, Ohio;
Barnes Woodhall, M.D., Durham, North Carolina (by invitation);
Halford Hallock, M.D., New York, N. Y.

FRIDAY, JUNE 28

rning Session

Future Development of Postgraduate Training in Orthopaedic Surgery.
Ralph K. Ghormley, M.D., Rochester, Minnesota.
Discussion: Guy A. Caldwell, M.D., New Orleans, Louisiana;
A. R. Shands, Jr., M.D., Wilmington, Delaware;
Steele F. Stewart, M.D., Honolulu, Hawaii;
Theodore A. Willis, M.D., Cleveland, Ohio;
Philip D. Wilson, M.D., New York, N. Y.;
Robert I. Harris, M.B., Toronto, Ontario, Canada;
Ralph K. Ghormley, M.D.

Report of the Committee on Infantile Paralysis.
Robert W. Johnson, M.D., Baltimore, Maryland.
Discussion: A. R. Shands, Jr., M.D., Wilmington, Delaware;
A. Bruce Gill, M.D., Philadelphia, Pennsylvania;
Robert W. Johnson, M.D.

The Newer Pathological and Physiological Concepts on Anterior Poliomyelitis and Their Clinical Interpretation.
Arthur Steindler, M.D., Iowa City, Iowa.
Discussion: H. Relton McCarroll, M.D., St. Louis, Missouri;
William T. Green, M.D., Boston, Massachusetts;
Arthur Steindler, M.D.

End Results Following Bone-Grafting for Non-Union of Carpal Scaphoid.
Gordon Murray, M.D., Toronto, Ontario, Canada (by invitation).
Discussion: Robert I. Harris, M.B., Toronto, Ontario, Canada;
Edwin F. Cave, M.D., Boston, Massachusetts.

President's Address.
J. Albert Key, M.D., St. Louis, Missouri.

ternoon Session

The Evaluation of Cortical and Cancellous Bone as a Grafting Material: A Clinical and Experimental Study.
LeRoy C. Abbott, M.D., San Francisco, California;
Edwin R. Schottstaedt, M.D., San Francisco, California (by invitation);
J. B. deC. M. Saunders, M.B., San Francisco, California (by invitation);
Frederic C. Bost, M.D., San Francisco, California.
Discussion: Ralph K. Ghormley, M.D., Rochester, Minnesota;
Fremont A. Chandler, M.D., Chicago, Illinois;
LeRoy C. Abbott, M.D.

Survival in Bone Sarcoma.
Harry Platt, F.R.C.S., Manchester, England.
Discussion: Dallas B. Phemister, M.D., Chicago, Illinois;
Philip D. Wilson, M.D., New York, N. Y.;
Henry W. Meyerding, M.D., Rochester, Minnesota;
Harry Platt, F.R.C.S.

Subtalar Bone Block (Arthrorisis) for Certain Types of Flat Feet. A New Operative Procedure.
C. J. Basile, M.D., Baltimore, Maryland (by invitation);
W. L. Waldrop, M.D., Baltimore, Maryland (by invitation);
Allen F. Voshell, M.D., Baltimore, Maryland;
Moses Gellman, M.D., Baltimore, Maryland (by invitation).
Discussion: Frank D. Dickson, M.D., Kansas City, Missouri;
Oscar L. Miller, M.D., Charlotte, North Carolina;
H. Relton McCarroll, M.D., St. Louis, Missouri;
Robert I. Harris, M.B., Toronto, Ontario, Canada;
Allen F. Voshell, M.D.;
C. J. Basile, M.D.

Fracture-Dislocation of the Ankle with Fixed Displacement of Fibula behind the Tibia.
David M. Bosworth, M.D., New York, N. Y.
Discussion: Oscar L. Miller, M.D., Charlotte, North Carolina;
Robert I. Harris, M.B., Toronto, Ontario, Canada.

Medical Electronics; Electromyographic Studies of Muscle Action Currents.
Nicholas S. Ransohoff, M.D., New York, N. Y.
Discussion: Arthur Steindler, M.D., Iowa City, Iowa.

SATURDAY, JUNE 29

Morning Session

Symposium on the Complications of Old Fractures of the Neck of the Femur and Their Treatmen
Philip D. Wilson, M.D., New York, N. Y., *Chairman.*
Complications of Fractures of the Neck of the Femur.
Harold B. Boyd, M.D., Memphis, Tennessee;
I. L. George, M.D., Memphis, Tennessee (by invitation).
The Pathology of Ununited Fractures of the Neck of the Femur.
Dallas B. Phemister, M.D., Chicago, Illinois;
Mary S. Sherman, M.D., Chicago, Illinois (by invitation).
Results of Treatment of Old Fractures of the Neck of the Femur by Bone Grafting Combine with Internal Fixation.
Robert I. Harris, M.B., Toronto, Ontario, Canada.
Non-Union in Fractures of the Neck of the Femur. Treatment by Schanz Osteotomy.
Walter P. Blount, M.D., Milwaukee, Wisconsin.
Results of Treatment by the Whitman Reconstruction Operation.
Arthur Krida, M.D., New York, N. Y.
Arthrodesis of Hip for Ununited Fractures.
A. Bruce Gill, M.D., Philadelphia, Pennsylvania.
Results of Treatment by Vitallium Mold Arthroplasty.
M. N. Smith-Petersen, M.D., Boston, Massachusetts;
William A. Law, M.B., Liverpool, England (by invitation).
Results of Treatment by Trochanteric Arthroplasty.
Philip D. Wilson, M.D., New York, N. Y.
Hexagonal Method of Osteotomy.
James Dickson, M.D., Cleveland, Ohio.
Discussion: Harry Platt, F.R.C.S., Manchester, England;
Carl E. Badgley, M.D., Ann Arbor, Michigan;
Paul C. Colonna, M.D., Philadelphia, Pennsylvania;
W. W. Plummer, M.D., Buffalo, New York;
Harold B. Boyd, M.D.;
Mary S. Sherman, M.D.;
Walter P. Blount, M.D.;
Philip D. Wilson, M.D.

On Friday evening, June 28, the Annual Association Banquet was held, and on Thursday and Saturday, at noon, there were Executive Sessions.

LeRoy C. Abbott, M.D., San Francisco, California, is President of the Association for the coming year.

Officers, members to committees, and new members were elected, as follows:

Officers

President-Elect: Robert I. Harris, M.B., Toronto, Ontario, Canada;
Vice-President: Harold R. Conn, M.D., Akron, Ohio;
Secretary: C. Leslie Mitchell, M.D., Detroit, Michigan;
Treasurer: Frank D. Dickson, M.D., Kansas City, Missouri.

Committee Members

Membership Committee:
A. R. Shands, Jr., M.D., Wilmington, Delaware (for the unexpired term of Guy A. Leadbetter, deceased);
William T. Green, M.D., Boston, Massachusetts.
Program Committee: Robert V. Funsten, M.D., Charlottesville, Virginia.
Research Committee: Halford Hallock, M.D., New York, N. Y.

Representatives

- American College of Surgeons: William E. Gallie, M.D., Toronto, Ontario, Canada.
- American Board of Orthopaedic Surgery: Fremont A. Chandler, M.D., Chicago, Illinois (Clarence H. Heyman, M.D., Cleveland, Ohio, Alternate).

New Members

Rufus H. Alldredge, M.D., New Orleans, Louisiana;
Lenox D. Baker, M.D., Durham, North Carolina;
George O. Eaton, M.D., Baltimore, Maryland;
John A. Heberling, M.D., Pittsburgh, Pennsylvania;
Raymond E. Lenhard, M.D., Baltimore, Maryland;
William M. Roberts, M.D., Gastonia, North Carolina;
Walter G. Stuck, M.D., San Antonio, Texas.

CHARLTON WALLACE

1872–1946

Among the many orthopaedic surgeons in New York City who have contributed to the betterment of the specialty, Dr. Charlton Wallace deserves more than passing notice. A native of Kentucky, Dr. Wallace possessed much of the social charm so commonly associated with the southern gentleman of the old school. His medical degree was obtained from the College of Physicians and Surgeons, Columbia University, in 1898. The respect in which his classmates held him was shown when they elected him as permanent president of his class.

Dr. Wallace's training in the special branch of surgery which he followed was received, for the most part, at the Hospital for the Ruptured and Crippled, where he served first as assistant and later became Attending Orthopaedic Surgeon. He was also on the staffs of the Polyclinic Hospital, New York City, and St. Agnes Hospital, White Plains, New York. His prime interest was in crippled children, and he devoted his life to them.

From 1905 to 1913 he was Orthopaedic Surgeon in charge of the East Side Free School for Crippled Children. In the early part of his career, he was in charge of experimental work in orthopaedics at Sea View Hospital. He was instrumental in establishing the Neponsit Beach Hospital for Children, Rockaway Beach. He was surgeon in charge of establishing the St. Charles Hospital for Crippled Children, Port Jefferson, Long Island, and was Chief Surgeon from 1907 to 1920. As a result of his interest in the rehabilitation of those disabled through industry and accidents, he was a member of the staff of the Reconstruction Hospital in New York from 1918 to 1923. Since 1929, he had been Surgeon-in-Chief of the New York State Reconstruction Home, West Haverstraw, an institution which he had helped to plan for the betterment of crippled children. He was Professor of Orthopaedic Surgery at Cornell University Medical College from 1913 to 1935.

Dr. Wallace died at his home in Chappaqua, New York, on August 16, 1946.

At the time of his death, he was Professor of Orthopaedic Surgery, New York Polyclinic Medical School and Hospital; and Consulting Orthopaedic Surgeon at the Hospital for Special Surgery, St. Charles Hospital for Crippled Children, St. Agnes Hospital, and Stamford Hospital in Stamford, Connecticut. He was a member of the New York Academy of Medicine, a Diplomate of The American Board of Orthopaedic Surgery, and a Fellow of the American College of Surgeons and of The American Academy of Orthopaedic Surgeons. He had been active as a member of The American Orthopaedic Association since 1907, but for the past few years was an Emeritus Member.

ROYAL WHITMAN

1857–1946

Royal Whitman was born in Portland, Maine, on October 24, 1857. He received his degree of Doctor of Medicine from Harvard Medical School in 1882, and for a while he practised in Boston. He was a charter member of the Tavern Club in Boston. He went to New York in 1889 and became associated with Dr. Virgil P. Gibney, at the Hospital for the Ruptured and Crippled. The association with this Hospital continued until 1929 when, after forty years of continuous service, he retired from both hospital and private practice. He moved to England, where he remained for about thirteen years, returning to his own country in 1943.

He died in New York City on August 19, 1946. Three days before his death he received an invitation to represent this country, as a guest of the French Government, at a meeting to celebrate the one hundredth anniversary of the founding of the French Academy of Surgery.

Dr. Whitman was a member of many medical organizations both here and abroad, but he valued most his Fellowship in the Royal College of Surgeons, and his membership in The American Orthopaedic Association, of which he was President in 1895.

He was an indefatigable worker. His was the opinion that, in orthopaedics, the out-patient department or clinic was an indispensable and integral part of the Service. The patients were seen first in the out-patient department and, after their stay in the Hospital for operative or non-operative treatment, returned to it for follow-up care or observation. This unit of service included both indoor and dispensary care. Hence, he, as well as all of his associates, attended the out-patient clinic. The clinic hours ran from one to three in the afternoon and so prompt was his arrival that watches could be set at one o'clock when he entered the Hospital. He had little patience with an assistant who came late or offered excuses for irregular attendance. In this, as in so many other respects, he set his assistants an excellent example.

Dr. Whitman loved orthopaedic surgery and sought continuously and zealously to advance it. To those who saw him and worked with him four or five days a week, he seemed to be thinking of nothing but orthopaedics. During a lull in clinic work in the afternoons the subject discussed was never art, literature, music, or politics, but always orthopaedic surgery,—a difficult case for diagnosis, surgical technique, mechanical or surgical principles, or orthopaedic literature. Dr. Whitman read extensively and was thoroughly informed on the orthopaedic literature in English, French, and German; he expected all of his associates to be equally well informed and up to date, so that discussions, which were very frequent, would be most fruitful and thought-provoking.

Dr. Whitman was a profound student of orthopaedic surgery, a pioneer, and a pathfinder. He was always trying out new procedures,—either those he initiated or those suggested by others. He had an insatiable curiosity about the pathogenesis of orthopaedic diseases and deformities, and an imagination which led him continuously to seek new methods of manipulative or surgical correction of musculoskeletal defects. He was his own sternest critic and never reported favorably upon any technique or procedure until he himself was thoroughly convinced of its usefulness. When he became convinced of the value of any treatment, he would, through addresses or medical essays, hammer away at the profession until his opinion was accepted.

Despite his intense interest in operative surgery, he never overlooked the opportunities and advantages of manipulative treatment or the manual correction of deformities, of which he was a master. Although short of stature and thin, he many times surprised his young and more vigorous assistants by the rapidity and ease with which he would correct a resistant deformity over which they had labored ineffectually. In the days when the use of great manual force was condoned in the correction of a club foot or the reduction of a congenital dislocation of the hip, he exhibited remarkable dexterity and strength in overcoming manually the resistance of contracted tissues and overcorrecting a deformity.

Dr. Whitman was particularly insistent upon a thorough knowledge of mechanical principles, the pathology of deformities, and the observance of these in therapeusis. Braces to him were intended for the support of the trunk or limbs, and not for the correction of deformities. First an equinovarus of the foot, a flexion at the hip or the knee, or a rigid flat foot had to be corrected; then, and then only, might the surgeon apply a brace. Woe to the assistant who did not obey this rule!

Dr. Whitman was truly a master surgeon. He was second to none in speed, dexterity, thoroughness, and careful handling of tissues. He religiously avoided undue or excessive trauma, and was ever mindful of the fact that the recovery of tissues operated upon depended directly upon the gentleness with which they were treated. "Treat the tissues lovingly" was the unwritten but ever-present motto of the amphitheater. Two factors contributed outstandingly to Dr. Whitman's ease and speed at the operating table. He was an excellent anatomist and, through hints dropped here and there, it was evident that he

ROYAL WHITMAN

kept reviewing anatomy; second, on the day before an operation he continuously reviewed what he contemplated doing, and hence he came to the operating table with a definite plan of procedure. He avoided complicated operations, believing that the goal could be attained through simple measures. He always avoided multiple operations at one session, on the basis that the usual orthopaedic operation was rarely an emergency procedure, and that the end result would be better if he used several simple separate operations.

He taught orthopaedic surgery for forty years, both at the College of Physicians and Surgeons of Columbia University and at the Hospital for the Ruptured and Crippled. His love for orthopaedic surgery made him a most generous teacher, who sought to transmit his experiences and information to whoever showed an interest and would listen. His method of teaching was not always a placid procedure. He often used the difficult, and not always agreeable, method of sarcastic criticism. This at times was vexing. His students, however, soon recognized the light in his eyes and the smile on his lips, and knew that there was no malice in the sarcasm. He meant only to emphasize indelibly some point in observation, diagnosis, or surgical technique. To the less understanding students and visitors, this pedagogic method was disconcerting. Those who knew Dr. Whitman well, however, realized that when he was sarcastic he would teach much.

As an investigator and teacher, Dr. Whitman was undoubtedly one of the great contributors to the advancement of orthopaedic surgery in our country. His text book on orthopaedic surgery is a classic. Dr. Whitman contributed a great many essays on orthopaedic problems. These were published in

English, but often were translated or abstracted in foreign languages, so that his teachings went to every corner of the world and to all medical circles. Dr. Whitman originated several methods of treatment, which have been universally acknowledged and adopted as classical procedures in orthopaedic surgery. He initiated the abduction treatment for fractures at the hip. His insistence on a method which created the opportunity for repair of a fractured hip gave the impetus to extensive clinical research and to the splendid progress which has been made in the last two decades in the management of fractures at the hip. He devised the operation of astragalectomy and backward displacement of the foot for paralytic calcaneus,—an operation which formerly was generally accepted for stabilization of the paralytic calcaneus foot. Dr. Whitman's exhaustive studies on flat or weak feet led to the establishment of a most effective system of treatment, including the use of the Whitman foot brace. His contributions to orthopaedic surgery become incalculable when one contemplates the many physicians whom he instructed and inducted into productive orthopaedic surgery.

In the death of Dr. Royal Whitman, orthopaedic surgery has lost an ardent and profound student, a splendid teacher, and a master surgeon. His legacy to his students is a love for orthopaedic surgery, devotion to the physically handicapped, and a determination to cure the cripple.

HERBERT ALTON DURHAM

1884–1946

Dr. Herbert Alton Durham died suddenly at Shreveport, Louisiana, on March 13, 1946, at the age of sixty-two. He was Surgeon-in-Chief of the Shriners' Hospital in Shreveport and an outstanding orthopaedic surgeon. Dr. Durham spent his boyhood on a farm in Vermont and received the degrees of A.B. in 1905 and M.D. in 1909 from the University of Vermont. After serving a general internship, he became a resident at the New York Orthopaedic Hospital. Dr. Russell H. Hibbs was Chief Surgeon of the Hospital at that time, and had just announced his operation for spine fusion. He was impressed by Durham's ability and, at the completion of his residency, sent him abroad on a travelling fellowship. The greater part of the year was spent in England under Sir Robert Jones, and in Austria and Germany.

With the onset of the first World War in 1914, he returned to New York and became a member of the staff of the New York Orthopaedic Hospital. When the United States entered the War, Durham was at once commissioned in the Army and went to England with the first contingent of orthopaedic surgeons under the leadership of Dr. Joel E. Goldthwait. Durham served under Sir Robert in a British Military Hospital until the end of the War, when he again returned to the New York Orthopaedic Hospital, this time as an Attending Surgeon.

In 1923 he was appointed Surgeon-in-Chief of the Shriners' Hospital at Shreveport, Louisiana, in which capacity he served until his death. He also was attending orthopaedic surgeon at the Highland, North Louisiana State, and Tri-State Sanitaria. He was an exceptionally skillful technician and a capable mechanic. These qualities, combined with a sound surgical judgment, accounted for his great success and his high reputation. He devised an apparatus for leg lengthening, an operation for correction of internal rotation of the hip in spastic paralysis, and a technique for transplantation of the biceps femoris.

He was a member of The American Academy of Orthopaedic Surgeons and of the American Medical Association, a Fellow of the American College of Surgeons, and a member of the Clinical Orthopaedic Society and of the Eastern State Orthopaedic Club. He was an out-of-doors man and got his recreation by shooting, riding, and golf.

He is survived by his wife, Beatrice Anderson Durham, to whom he was married in England in 1918, and by two children, Lieutenant Herbert A. Durham, Jr., of the Army Air Force, and Mrs. Harry V. Bascom of Shreveport.

Current Literature

HUMAN EMBRYOLOGY. Bradley M. Patten, Ph.D. Philadelphia, The Blakiston Company, 1946. $7.00.

This monumental work of scientific scholarship, by the distinguished Professor of Anatomy in the University of Michigan Medical School, is a complement and sequel to his previously published and well-known volumes on the embryology of the chick and of the pig. Not only is the text authoritative and final, but it is richly illustrated with drawings and photographs, mostly original, made by the author or under his supervision, of which fifty-three are in color. There is an elaborate bibliography of over one thousand titles.

Especial attention is devoted to the circulatory and nervous systems, upon which Dr. Patten has done much original research. The book is a model of lucid exposition, including within compact limits the essence and details of so vast and complex a subject. It is a masterpiece,—a memorable contribution to the knowledge of human embryology.

ENTORSES DU COU-DE-PIED ET ENTORSES DU GENOU. INTRODUCTION A L'ÉTUDE DE L'ARTHROGRAPHIE (Sprains of the Ankle and Sprains of the Knee. Introduction to the Study of Arthrography). L. Léger et C. Olivier. Paris, Masson et C^ie^, 1945. 200 francs.

During our modern ways of living—with war, sports, and increasing numbers of youth organizations—sprains of the joints are becoming more and more frequent, and the majority of them occur in the ankle and the knee joint. Their diversity is very great; their study, although begun several centuries ago, has always left the practitioner at a loss, not only about their classification, but especially about their treatment. One of the merits of this book lies in the fact that Léger and Olivier have observed a great many such sprains and have been especially interested in their surgical treatment. The main features of the publication are those which characterize a French mind,—clearness, logic, and the didactic spirit. Its value is increased by the completeness of the study.

In the first chapter the authors study sprains of the ankle, with which, of course, they include the tarsus. They review consecutively the macroscopic and microscopic pathology, the physiopathology, etiology, mechanism, clinical study, complications, diagnosis, evolution, and treatment. One of the main features of this chapter is a very complete study of the ideas of Leriche, which have been prevalent during the last few years. The authors have reduced them to their just proportion, and have come to the conclusion that the anatomical findings prove the frequent presence—if not the constant presence—of macroscopic lesions in the ligaments going from the elongation to the disinsertion, with or without partial or complete rupture. They describe the various treatments in detail,—the physiotherapeutic procedures; the various bandages, which are amply illustrated; the treatment by novocain injection; the importance of relative immobilization; and the various surgical interventions, about which they show some skepticism. The sequelae of this type of sprain are described,—namely, laxity of the ligaments, diastasis, chronic arthritis, painful osteoporosis, and posttraumatic ossification.

The authors adopt the same plan in discussing sprains of the knee joint. Their study of the relative frequency of lesions of the lateral ligaments and the cruciate ligaments is very detailed, but in this chapter a most extensive and personal study is made of arthrography. Although the authors make a very judicious evaluation of the different non-surgical treatments—the infiltration of novocain, which they consider as a symptomatic treatment, immobilization, and physiotherapy—they give to surgical procedures the most important value.

More than fifty pages are devoted to "old sprains". The reader's attention is directed toward the diagnosis and surgical treatment of "unstable knees", and the authors review the different types of tenoplasty and tendon replacement, mentioning, among others, the names of Hey Groves, Mauck, and Bennett. Under "painful knees" is included a discussion of Pellegrini's disease. Chronic arthritis and traumatic lipo-arthritis are also considered. In this chapter the authors show a very marked tendency toward surgery.

This book does not include a statistical study or a bibliography, but it is so clear and practical that it will be read with interest not only by orthopaedic surgeons, but also by the general practitioner.

MEDICAL EDUCATION AND THE CHANGING ORDER. Raymond B. Allen, M.D., Ph.D. New York, The Commonwealth Fund, 1946. $1.50.

The Challenge to Medical Education is the title of the first chapter of this small volume. In it the author, who is Executive Dean of the Colleges of Dentistry, Medicine, and Pharmacy at the University of Illinois, makes many interesting general observations:

"The study of medicine . . . must embrace the study of life in all its aspects—physical, psychological, and social."

"Changes in medical education in this country reflect changing cultural, scientific, social, economic,

and political conditions and follow an evolutionary—rather than a revolutionary—pattern typical of American institutions generally. The current problem is to identify, strengthen, and secure the wider acceptance and application of those trends in medical education and medical science which best serve the needs of the people."

"Medical education, like medical science, is an experimental art dependent wholly for success on the learning, skills, imagination, resourcefulness, integrity, and courage of individuals."

The historical background and foundations of medical education are discussed at length. In order are considered the preparation for the study of medicine, the essential factors in undergraduate medical education and in graduate study, the problems in medical education, and opinions about their solution.

The author makes a plea for the adequate support of medical education and research. He points out, too, the responsibility of American medicine in tomorrow's world: "The hopeful and talented of many lands will need and want opportunities to study in our universities; we must make this possible to the limit of our resources. We must help, too, in the reestablishment of our sister institutions in war-ravaged countries—particularly of their libraries. We must without stint pay our debt to the scholarship, science, and humanism of Europe without which there would be no western civilization. We should not deny this obligation because a misguided few have allowed their science and scholarship to serve the ends of tyranny. The medicine, science, and scholarship of tomorrow's world must forever be free to serve the peaceful needs of all mankind."

This is one of the monographs issued by the Committee on Medicine and the Changing Order of the New York Academy of Medicine. It is well written and merits a wide reading.

Manual of Diagnosis and Management of Peripheral Nerve Injuries. Robert A. Groff, M.D., and Sara Jane Houtz, B.S. Philadelphia, J. B. Lippincott Company, 1945. $6.00.

This book represents an amazing feat on the part of the authors, since it was written during a period of intensive clinical activity at the worst period of the year—the monsoon season—in Burma. They were presumably attempting to have available for the Military Services, in time for the expected invasion of Japan, a useful guide in methods of examination of peripheral-nerve injuries. The unforeseen end of World War II must have made them wonder if publication of the work was warranted, but whatever its current usefulness may be, it forms an impressive testimonial to their industry under adverse circumstances.

Nearly half of the book is devoted to a series of diagrams, indicating the proper method of examination of most of the voluntary muscles of the body. This is the most useful part of the volume; it represents an extension of the series of pictures published by the Medical Research Council of Great Britain under the title of "Aids to the Investigation of Peripheral Nerve Injuries", and includes more of the musculature. It is not surprising that the authors, engaged as they were in the practical problems of treating wounded soldiers, placed such emphasis on teaching their personnel exactly how to examine muscle strength. When a more leisurely and definitive volume on peripheral-nerve injuries appears, incorporating all of the lessons learned in this War, it is to be hoped that it will include pictures, illustrating examinations of specific muscles, as complete as those in this book and as clear as those in the pamphlet of the Medical Research Council.

The authors have discussed only briefly the value of the various methods of electrodiagnosis and of management of peripheral-nerve injuries, proposed during World War II, realizing that only after follow-up studies have been completed on the thousands of cases handled can the true end results be determined.

They do advocate one obsolete procedure, to which their attention should be drawn. On page 57 they state that the inferior cervical ganglion and the upper two thoracic sympathetic ganglia are removed for causalgic pain in the upper extremity. It has long since been shown by J. C. White that this postganglionic sympathectomy (which unnecessarily denervates the head as well, and produces a Horner's syndrome) should be abandoned in favor of a preganglionic operation, with division of the sympathetic trunk below the third thoracic ganglion and of the rami communicantes to the second and third thoracic ganglia.

The American Hospital. E. H. L. Corwin, Ph.D. New York, The Commonwealth Fund, 1946. $1.50.

This monograph is one of a series of studies issued under the auspices of the Committee on Medicine and the Changing Order of the New York Academy of Medicine. In its 226 pages there is an abundance of information about the American hospital, past and present, with the trends indicating the pattern for the future. From the small beginning of 178 hospitals (146,472 patients) in 1873, when the first list of hospitals in the United States was compiled, the number had grown in 1943 to 4,655 (15,374,698 patients), with corresponding increases in physical assets and capital investment. The greatest single impetus to hospital growth was the evolution of surgery; in 1942, 44.7 per cent. of hospital patients were surgical cases.

Among the topics discussed are the types of hospitals, with the general hospital constituting the largest group; the financial structure; hospital planning and construction; and the distribution and

utilization of hospitals. A chapter is devoted to the Outpatient Department, which has superseded the dispensary. This Department, which reaches as many patients as does the hospital, affords the best opportunity for the practice of preventive medicine. In general, its value as an educational medium has not been fully realized. The importance of the hospital as a teaching center and the problem of the chronically ill are also stressed.

In the closing chapter, Retrospect and Prospect, the entire volume is fully summarized, with brief comment on the many phases previously discussed.

The importance of the hospital in the health of the community and as a training center, under changing conditions which are partly the result of the War, makes this book of value to those interested in the field of medicine and the care of the sick.

La Inmovilización Enyesada: Su Técnica y Sus Aplicaciones (Plaster Immobilization: Its Technique and Its Uses). Nino Valentín Zucchi. Buenos Aires, "*El Ateneo*", 1945.

This volume, dedicated to the memory of Vittorio Putti, seeks to show how to use plaster-of-Paris bandages in the treatment of disabilities in all parts of the body. The author, from his experience in the Traumatological Institute in Montevideo, Uruguay, feels that its use is not well known and that casts are frequently applied badly, to the harm of the patients. After discussing its discovery by Mathijsen and the chemistry of anhydrous calcium sulfate, the author describes many types of apparatus designed to facilitate the making of plaster casts for different parts of the body.

Numerous excellent illustrations are given; one, in particular, shows the areas of the body which should be padded when plaster casts are applied. The technique of applying edging, straps, and buckles is well described. Patterns for making special plaster molds for the facial bones and other special parts of the body are shown.

This is a complete treatise on plaster application. It is modeled on the older European texts, and reminds one of Calot's treatise. It is far more adequate in its treatment and illustrations than is any extant treatise in English. One can recommend it as a helpful text to anyone who uses plaster-of-Paris casts.

A Complete Outline of Fractures, Including Fractures of the Skull. J. Grant Bonnin, M.B., F.R.C.S. Ed. 2. London, William Heinemann Ltd., 1946. 30 shillings.

This is a straightforward, systematic, comprehensive, and well-illustrated book. It will be useful to the surgeon, especially the occasional surgeon, but it is probably presented in too much detail for most students. In general the book is up-to-date. The author is wise in not being one season ahead of the fashion. He commendably avoids that misleading dogmatism and confident overstatement which have marred more than one great book on fractures. He has chosen a plastic surgeon, who speaks with authority on maxillofacial injuries, to write the chapter on fractures of the face and jaws.

A Bibliography of Infantile Paralysis, 1789–1944. Edited by Morris Fishbein, M.D.; compiled by Ludvig Hektoen, M.D., and Ella M. Salmonsen. Philadelphia, J. B. Lippincott Company, 1946. $15.00.

This bibliography, prepared under the direction of the National Foundation for Infantile Paralysis, traces the literature on poliomyelitis back to 1789, when the disease was first described. The references are arranged chronologically; as would be expected, the preponderance of the work on this subject has been published in the last ten years. As explained in the Preface, much of the foreign literature of the past few years is not yet available, so that a supplement to the bibliography is planned to take care of these references.

The volume contains more than 8000 references to publications on infantile paralysis. Since a short abstract of the article is included in most instances, the book will be invaluable to the worker in this field. In addition, a detailed, carefully prepared subject index, as well as an index of authors, adds immeasurably to the value of the volume. It is a fine piece of work, which will have extensive usefulness.

Medical Services by Government: Local, State, and Federal. Bernhard J. Stern, Ph.D. New York, The Commonwealth Fund, 1946. $1.50.

This book represents one of the studies undertaken by the Committee on Medicine and the Changing Order of the New York Academy of Medicine. It contains a wealth of factual data on the extent of medical care as provided by local community, state, and Federal Government.

The development of this service has been gradual. In the early days of the Colonies and of the United States, the care of the indigent sick was assumed by voluntary private philanthropy. As States were organized, they assumed this responsibility. Many of the state laws were based on the Elizabethan poor laws. The first hospitals in the United States were really infirmaries in poorhouses. The development of town or city, county, and state institutions preceded the establishment of Government-controlled institutions.

The United States Marine Hospitals represent the oldest venture of the Federal Government in

the field of medical care, and their operation was the initial function of the Public Health Service. Official Public Health Services concerned with the control and prevention of disease have developed throughout the years as a separate type of Government service.

New patterns of medical care are now being formulated, and the role of local, state, and Federal governments in the field is shifting. Dr. Stern traces these developments and indicates the changing emphasis and changing points of view concerning the relative responsibilities of the local community, the state government, and the Federal Government.

The recent wartime activities of the Federal Government have further extended Government medical services. The book closes with a summary of the medical services to veterans.

Occupational Therapy for the Limbless. Phyllis Lyttleton, C.S.P., M.A.O.T. London, H. K. Lewis and Company, Ltd., 1946. 3 shillings.

This pamphlet of forty pages is an appeal for sympathetic understanding of the problems of the amputee. The author was an occupational therapist in one of the hospitals of the Ministry of Pensions, to which came patients "who had lost one arm, one leg, both hands, both legs, and [with] all possible combinations of these disabilities". She reports her experiences in adapting crafts for these patients, which were useful not only as therapy and to help pass the months of waiting until their prostheses were fitted, but also in building their hopes for the future.

The psychological approach to these patients is most important and is emphasized throughout the book. The author feels that the intelligent, sympathetic occupational therapist can make a real contribution to the reeducation of these patients, mentally as well as physically.

Demonstrations of Operative Surgery for Nurses. Hamilton Bailey, F.R.C.S. Baltimore, The Williams and Wilkins Company, 1945. $3.50.

Practical demonstrations for student nurses were the basis of this excellent textbook. It will be especially interesting to those of the nursing profession who wish to excel in the technique and skill of work with surgeons. Any nurse would benefit by using this book as a reference, for it includes detailed descriptions of many operations; every operating-room nurse should include it in her professional library.

The illustrations are excellent and vividly portray most major operative procedures.

Curare — Intocostrin. New York, E. R. Squibb and Sons, 1946.

This volume consists of a well-constructed collection of recent articles on curare. The subject matter includes fundamental research in the chemistry and pharmacology of the drug, and its therapeutic and clinical contributions. As an exhaustive reference source, this book will serve a very useful purpose, especially in light of the increased interest in the clinical applications of curare. No editorial opinion is expressed in relation to the collection of articles. In the form of an appendix, however, an attempt is made to correlate accepted experimental data on curare with the recent concepts of neuromuscular conduction. This discussion should prove of great interest to the clinician, but is, of course, largely speculative in approach.

On the Different Types of Intracapsular Fractures of the Femoral Neck. A Surgical Investigation of the Origin, Treatment, Prognosis and Complications in 365 Cases. Per Linton. *Acta Chirurgica Scandinavica,* **90**: Supplementum 86, 1944.

In a series of 365 fractures of the neck of the femur, 200 were followed in detail and seventeen were reported without roentgenograms. The mechanism of causation and the significance of abduction, intermediate, and adduction fractures are discussed. It is concluded that the determining factors were the force of the blow and the strength of the skeleton. Variation in direction apparently had little effect. The fractures differ more in degree of dislocation than in type.

Abduction fractures are frequently stable. The writer avoids the use of the term "impaction" and substitutes "stability", because of the pitfalls in undertreating these fractures. He recommends nailing abduction fractures, if there is any doubt of their stability.

The significance of the obliquity of the fracture line is discussed in great detail. Accurate methods of determination of the angle are necessary. Obliquity alone is not a conclusive factor in indicating a poor prognosis. Combined with too horizontal a position of the nail or a posterior defect, increased obliquity is associated with non-union in a significantly increased number of cases. The greatest factor in producing poor results is increased age.

The frequency of aseptic necrosis of the femoral head is greater in the fractures with pronounced displacement. In a comparative series in which multiple small nails were used, the frequency of aseptic necrosis was apparently less.

Four cases of subtrochanteric osteotomy, simultaneous with the reduction and fixation, are recorded. In two additional cases, an osteotomy was performed soon after the primary reduction and nailing. In all of these cases, a cast was applied to maintain the position of the osteotomy; the cast was the chief objection to the method. The results were good. The total frequency of union, in cases nailed according

to the method of Smith-Petersen and Johansson, was 83.6 per cent.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

Reparative Surgery of Compound Battle Fractures in the Mediterranean Theater of Operations. Oscar P. Hampton, Jr. *Annals of Surgery,* 122: 289–332, 1945.

This important article provides a comprehensive presentation of an organized plan for the surgical care of serious wounds. The program rests upon sound surgical principles, and the directions for its implementation are set forth. The paper is too comprehensive to be abstracted, but it should be read and studied by surgeons who deal with compound fractures. The author believes that, whatever the value of blood and penicillin may be as surgical adjuncts, further improvement in results probably depends upon perfection of surgery, for which there is no substitute.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

A Comparative Study of 100 Fractures of the Shaft of the Femur in Which One-Half Were Treated with Penicillin. Spencer A. Collom, Jr., and William McD. Ewing. *Annals of Surgery,* 122: 773–792, 1945.

Of a series of 100 consecutive fractures of the femur, eighty-two were compound fractures. These compound fractures were studied in groups, arranged according to the treatment. The keynote of the treatment is sounded in the following quotation from Churchill (*Annals of Surgery,* 120: 268, 1944): "A highly significant and far-reaching advance in military surgery has taken place in the base hospitals with the development of what may be called *reparative surgery.* Wounds left unsutured at the initial operation are routinely closed by suture, usually at the time of the first dressing. With the use of penicillin as a safeguard against infection, the management of wounds complicated by fracture or joint involvement has been revolutionized." The present study substantiates the conclusion that, while penicillin and blood are valuable aids in preventing local and systemic invasion by penicillin-sensitive organisms, they are not a substitute for adequate surgery. The value of reparative surgery is emphasized. This means secondary débridement and closure between the fifth and tenth days. The majority of fractures of the femoral shaft could be realigned by skeletal traction, but internal fixation was performed when indicated and the results were satisfactory. The time required for bone healing varied in proportion to the duration of wound sepsis.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

The Use of Penicillin in the Treatment of Acute Hematogenous Osteomyelitis in Children. Report of Twelve Consecutive Cases. Edward L. Compere, William J. Schnute, and Lee M. Cattell. *Annals of Surgery,* 122: 954–962, 1945.

Hematogenous osteomyelitis in children from the age of three up to puberty usually originates in a skin lesion and is caused by hemolytic *Staphylococcus aureus* or *Staphylococcus albus*; this causes more bone damage than does the hemolytic streptococcus, which more often attacks children under the age of three. The sulfonamides have been shown to be useful in acute osteomyelitis, but some patients are sensitive to these compounds and in others the organism may be sulfonamide-resistant. Subsequent surgery has been required in many patients who apparently had been cured by the sulfonamides. In twelve consecutive patients, penicillin was successful; ten of these patients had been treated unsuccessfully with sulfonamides. Surgery of a minor nature was required in only four of the twelve cases. It is thought that penicillin is more effective than any other agent in acute osteomyelitis, but it must be emphasized that even its great value does not permit the omission of the well-established principles of medical and surgical care.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

The Pathogenesis of Localized Fibrous Lesions in the Metaphyses of Long Bones. C. Howard Hatcher. *Annals of Surgery,* 122: 1016–1030, 1945.

In a careful study of forty-five patients with metaphyseal fibrous defects in the bones of the lower extremities, it was found that fourteen also had epiphyseal disorders. Spontaneous healing was the rule; surgical eradication was necessary for the relief of pain in a few cases. The evidence indicates that metaphyseal fibrous defects are not localized, as is commonly thought. While the primary causes are unknown, there is enough similarity between the metaphyseal and the epiphyseal lesions to suggest a common pathogenesis.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

Delayed Internal Fixation of Compound Battle Fractures in the Mediterranean Theater of Operations. A Follow-Up Study in the Zone of Interior. Oscar P. Hampton, Jr. *Annals of Surgery,* 123: 1–26 and 238–275, 1946.

This is an extensive report of an end-result study of the use of delayed internal fixation in compound battle fractures. It merits reading in its entirety. The article substantiates the conclusion that a place has been established for delayed internal fixation. Of 332 fractures treated in accordance with this well-formulated program, the maximum achievable result was secured in 258 (77.2 per cent.). Complete figures on the series are given in comprehensive tables.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

The Incidence of Complications in the Use of Transfixion Pins and Wires for Skeletal Traction. Charles K. Kirby and William T. Fitts, Jr. *Annals of Surgery*, **123**: 27–31, 1946.

This is an encouraging report on the use of transfixing pins and wires. Three hundred and forty-two pins and wires were used in the treatment of 233 fractures of the long bones. Only one infection occurred,—an incidence of 0.33 per cent. Even in this case, neither osteomyelitis nor a draining sinus developed. There were a few minor complications, such as loosening, breaking, or slipping, but in no instance did these occurrences have any significant effect upon the course or the result.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

The Immersion Foot Syndrome. C. C. Ungley, G. D. Channell, and R. L. Richards. *The British Journal of Surgery*, **33**: 17–31, 1945.

This paper records the results of cases treated during 1941 and 1942. "Immersion foot" is stated to be a descriptive, but inaccurate, term for a syndrome produced by exposure of the extremities to a degree of cold insufficient to freeze the tissues.

There are four stages in the typical case of immersion foot: the period of exposure, and the prehyperaemic, hyperaemic, and posthyperaemic stages. The feet are cold, numb, swollen, and pulseless during exposure and immediately afterward; this is believed to be due to intense vasoconstriction. The next stage is accompanied by intense hyperaemia, increased swelling, and severe pain. The hyperaemia decreases and the pain and swelling are lessened during a period of from seven to ten days after rescue. Due to damage to the peripheral nerves, disturbances in sensation, sweating, and muscular atrophy and paralysis then appear.

After several weeks the feet become very sensitive to cold and, if exposed to a low temperature, they may remain cold for several hours. Hyperhidrosis frequently appears with this stage, and occasionally blisters and gangrene.

The prognosis depends upon the severity of the damage. Rapid warming of the tissues is condemned. Cold therapy in the hyperaemic stage may give relief, but should not be used earlier. Sympathectomy should not be used early, but may have its place in the late cold-sensitive state.

The authors consider in great detail the pathology and the methods of prevention and treatment. Accompanying the article are many excellent tables and illustrations.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

The Major Amputation Stump in Health and Disease. F. G. St. Clair Strange. *The British Journal of Surgery*, **33**: 31–41, 1945.

The ideal amputation stump is one that will allow the proper appliance to be worn without discomfort and without materially interfering with the patient's economic existence. The ideal lengths are stated as (1) below the knee, five and one-half inches from the joint line to the point of bone section; (2) above the knee, ten to twelve inches, measured from the tip of the greater trochanter; (3) below the elbow, seven inches from the tip of the olecranon; and (4) above the elbow, eight inches from the tip of the olecranon with the arm at the side.

The amputation stump assumes new physiological duties, and these vary with the type of artificial limb. The author goes into great detail in considering this new physiology.

The following points are brought out in discussing the operative technique:

1. Skin flaps should be cut so that they meet over the center of the stump without "dog ears". There should be no redundancy in these flaps.

2. The deep fascia should be maintained with the skin flap to ensure proper nerve supply and lymphatic drainage.

3. The bone and periosteum should be cut at the same level.

4. The nerves should not be intoxicated with alcohol.

5. Careful hemostasis should be accomplished. However, the author states that "drainage, even then, can rarely be dispensed with". If there is sepsis when the drain is removed in forty-eight hours, the skin flaps are separated and laid back.

Consideration is given to the guillotine amputation and the reamputation, where indicated. All such secondary amputations should be done through a clean field. The causes and the treatment of various affections are mentioned in some detail.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Penicillin Treatment of Acute Haematogenous Osteomyelitis. I. W. J. McAdam. *The British Journal of Surgery*, **33**: 167–172, 1945.

The criteria of success in the use of any drug in acute osteomyelitis are the control of the septicaemia or pyaemia and the control of the local infection, with the limiting of bone necrosis. A study of forty cases treated with penicillin indicates that this drug answers these criteria. There was but one death in the series, despite the fact that nineteen of these patients had staphylococcal septicaemia, nine had metastatic lesions, and ten had septic arthritis.

In twenty-nine cases the penicillin was administered intramuscularly, but in eleven cases the intra-

medullar route was employed, with a sternal-puncture needle inserted into the metaphysis of the involved bone. This latter method provides a high local concentration of the drug, as well as a satisfactory blood level.

The operative treatment of this group was very conservative. Of thirty-two with infection of the long bones, only five had operative treatment. Four of these operations were performed early in the series, before the full value of conservative treatment was appreciated; and the surgery in the fifth case was only incision and drainage of a soft-part abscess.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

SARCOMA OF THE METATARSAL BONES. A BRIEF REVIEW OF THE LITERATURE, WITH ONE PERSONAL CASE. Ivor J. Thomas. *The British Journal of Surgery*, **33**: 191–194, 1945.

A case of chondrosarcoma of the first metatarsal bone is presented. This tumor was said to have appeared ten months after an injury to the foot. Treatment was by amputation at the site of election. The patient was well fourteen months after the operation.

A review of the literature shows a small number of tumors of this type in the metatarsal bones. The reported rate of cure is about thirty-three per cent.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

METASTATIC OSTEOMYELITIS SECONDARY TO TROPICAL ULCER. Margaret M. Shepherd. *The British Journal of Surgery*, **33**: 352–357, 1946.

In eleven patients of a group of ninety-eight suffering from tropical sloughing phagedaena, ulcus tropicum, or Naga sore, metastatic lesions developed in the long bones remote from the ulcer. The cortex of the diaphysis was involved, and all lesions healed spontaneously.

A slight amount of pain and tenderness usually called attention to the lesion, and roentgenograms verified it. Usually the tropical ulcer had been present for two or more weeks before the onset of the pain, and occasionally the ulcer was entirely healed.

Roentgenographically, the cortex showed decalcification, followed later by a deposit of new bone periosteally, but never with much absorption of bone. There was no permanent disability.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

TENDON TRANSPLANTATION FOR RADIAL PARALYSIS. R. B. Zachary. *The British Journal of Surgery*, **33**: 358–364, 1946.

In assessing the results of tendon transplantation, the chief points to be evaluated are: (1) the range and power of extension of the fingers and thumb, (2) the range and power of wrist extension, (3) the range and power of wrist flexion, and (4) the range of flexion of the fingers.

The writer has studied fifty-seven cases. In twenty-four cases, both the flexor carpi radialis and the flexor carpi ulnaris were transplanted into the extensors of the digits. Where the palmaris longus was absent, the results were bad; but when it was present, about half of the patients showed good results. In twenty-nine patients only the flexor carpi ulnaris was transplanted, and 90 per cent. of these patients had good functional results.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

FRACTURAS DEL PIRAMIDAL (FRACTURES OF THE TRIANGULAR BONE). M. Riosalido. *Cirugía del Aparato Locomotor*, **2**: 322–331, 1945.

Fractures of the triangular bone are rare. The author collected thirty cases from the literature and adds six cases, personally observed. The condition is commonly associated with other carpal injuries. It is a fracture of compression, usually caused by a fall upon the palm of the hand. Diagnosis is not easy and depends upon the roentgenographic findings. Treatment consists of immobilization—effective, but not too rigorous—with a palmar splint, for from twenty to twenty-five days, followed by physiotherapy and exercise.

In one case there was a temporary disturbance of the ulnar nerve. In another case pain persisted, so that a support for the wrist was required for work. Normal recovery occurred in the others.—*John G. Kuhns, M.D., Boston, Massachusetts.*

PRINCIPIOS TERAPÉUTICOS EN LAS ARTRITIS TRAUMÁTICAS (THERAPEUTIC PRINCIPLES IN TRAUMATIC ARTHRITIS). Pablo Mendizábal. *Cirugía y Cirujanos*, **13**: 157–178, 1945.

This is a long, detailed article on the subject of traumatic arthritis. The anatomical and clinical conceptions of joints, as understood by the author, are given in some detail. The gross and microscopic pathology is given and the various tissues are described. The abnormal physiology of joint changes and of synovial function is explained. The intimate relation between the bone structure and circulation, especially with regard to the small blood vessels, veins, and lymphatics, is stressed, and the importance of small alterations is pointed out. Numerous joints and the various types of traumatic involvement are discussed. The author stresses the importance to joint function of the patient's general health and constitutional factors. Various mechanisms of trauma are given, and eighteen types of injuries to the joint are enumerated. These vary from severe external violence to minor repeated injuries.

The various types of therapy used in arthritis are discussed. A complete diagnosis with extensive

laboratory work is important, because the Wassermann and Kahn tests, the sedimentation rate, uric-acid determination, and blood count are all of importance. The author feels that metallic substances placed near joints in the treatment of fractures produce joint irritation and traumatic arthritis. This is a consideration in treatment. The indications for operations in traumatic arthritis are given, and the types of surgery include periarticular surgery on the capsule, ligaments, muscles, and tendons, and intra-articular surgery on the joint itself. The correction of bone alignment is indicated if a fracture near a joint is angulated. Among the types of surgery indicated are synovectomy, capsulotomy, tenotomy, osteotomy, arthrotomy, arthrodesis, arthroplasty, sympathectomy, and ganglionectomy. The general management includes treatment of focal infection, general systemic measures, immobilization of the joint, the use of heat, and the use of ultra-violet light.—*Louis W. Breck, M.D., El Paso, Texas.*

MALUNITED FRACTURES AND DISLOCATIONS. T. H. Somervill. *The Indian Journal of Surgery,* **7**: 85–95, 1945.

Although the textbooks usually describe the treatment for recent fractures, the fractures encountered in India, particularly in the country districts, are not presented for treatment immediately, but frequently have been treated by quacks or neglected entirely. Somervill presents an admirable study of malunited fractures and the methods of preventing malunion, based on experience gained during twenty-two years in a surgical center in southern India. He attaches importance to exercise and movement of all parts of the body, except those which must be immobilized; to a diet containing extra calcium and ample quantities of vitamins C and D; and to the administration of aluminum acetate for several months after the injury.

RECURRENT DISLOCATIONS OF THE SHOULDER JOINT. N. S. Narasimhan. *The Indian Journal of Surgery,* **7**: 123–133, 1945.

Narasimhan presents an admirable study of recurrent dislocation of the shoulder, based on a series of ninety-nine cases treated at the Madras General Hospital from 1938 to 1945. He reviews the theories of its causation, particularly those of Bankart and Codman, noting the frequency of its occurrence in epileptics and during the chronic spasms of tetanus. He believes that the treatment should be operative, describes seven types of operation, and reports a series of twelve cases operated upon, describing the pathology in each and the technical difficulties experienced with Bankart's procedure. He discusses the comparative merits of various operations, concluding that Bankart's, in which the capsule and the cartilage are sutured to the anterior rim of the glenoid, gives the best results.—*Robert M. Green, M.D., Boston, Massachusetts.*

LOS PIES ZAMBOS DOLOROSOS POSTRAUMÁTICOS EN LAS FRACTURAS DEL CUELLO DEL PIE. SUS VARIEDADES Y SU TRATAMIENTO (POST-TRAUMATIC PAINFUL VARUS FEET FOLLOWING FRACTURES OF THE ANKLE. TYPES AND TREATMENT). A. Velasco Zimbron. *La Prensa Médica Mexicana,* **10**: 27–28, 1945.

The many types of soft-tissue lesions and fractures which may be found in the ankle are enumerated. Non-union and malunion of fractures are the most important causes of persistent pain. The different types of fractures of the tibia and fibula at the ankle are all mentioned, and the reader is referred to Cotton's classification of Pott's fractures. Persistent pain following ankle fractures is usually due to a disorganization of the ankle joint, which the author calls a disharmonious relationship between the talus and the tibia.

In the treatment of the painful extremity, the simpler surgical procedures are of little value. The author recommends an arthrodesis of the ankle, and he describes his favorite type, which is a central bone graft. The joint is exposed laterally, and osteotomy is performed on the lower end of the fibula. The articular cartilage is removed from all joint surfaces. A bone graft, one centimeter by ten centimeters in size, is taken from a higher portion of the tibia and is placed across the ankle joint by inserting it into drill holes in the tibia and the talus. Details of the operation, the closure, and the postoperative immobilization are given. The author has treated ten cases, with solid fusion in all of them.

The article is well illustrated.—*Louis W. Breck, M.D., El Paso, Texas.*

L'EXAMEN RADIOGRAPHIQUE DU PIED BOT (ROENTGENOGRAPHIC EXAMINATION OF CLUB-FOOT). Pierre Marique. *La Presse Médicale,* **53**: 633–634, 1945.

The author maintains that congenital club-foot represents a true subluxation of the foot on the leg. This can be demonstrated by roentgenograms taken by the following technique: With the child flat on the back, the leg is externally rotated so that the bimalleolar axis is perpendicular to the plate. No effort is made with respect to the fore part of the foot. The central beam is centered over the bimalleolar axis, and exposures are made with the foot in complete flexion and extension. Attention is called to the fact that, in dorsal flexion, the degree of supination is markedly reduced.

On such bimalleolar profile views, the axis of the tibia normally passes through the posterior end of the talus when the foot is in extension. In flexion, the talus is displaced still farther posteriorly. In the club foot, the axis of the tibia lies well behind the talus when the foot is in extension.

For purposes of comparison and in order to determine the presence of irreducible equinus of the talus, the author recommends that the roentgenograms be made with the foot in flexion.—*Henry Milch, M.D., New York, N. Y.*

LE BILAN HUMORAL DES OSTÉOPATHIES DE FAMINE (FLUID BALANCE IN HUNGER OSTEOPATHIES). L. de Gennes et G.-H. Deltour. *La Presse Médicale,* 53: 678–679, 1945.

In a study of twelve cases of hunger osteopathy, the authors noted the loss of calcium, phosphorus, vitamin C, and vitamin D, and a qualitative and quantitative lack of lipoids and proteins. Although the calcium in the blood was relatively constant, there was a marked excretion of calcium in the urine.

In five cases the blood phosphatase was normal, but in one there was a mild increase and in five a marked increase in the phosphatase.

In five cases there was an increase in blood potassium with a disturbance in the calcium-potassium ratio.

In a certain number of cases, "opaque images of variable form", giving the impression of calcification of different organs, were found. The authors have termed these shadows "cutaneous creases", although they seem to arise from deposition of calcium in the subcutaneous tissues. They are never found in other emaciating conditions.—*Henry Milch, M.D., New York, N. Y.*

OSTÉOSARCOME ET MALADIE DE PAGET (OSTEOSARCOMA AND PAGET'S DISEASE). F. Layani et Cl. Olivier. *La Presse Médicale,* 54: 145–146, 1946.

The authors report the case of a woman, aged eighty, in whom sarcoma developed as a result of Paget's disease. During the course of the disease, roentgenotherapy controlled the pain. Amputation was performed in the lower third of the femur, but pulmonary involvement was the cause of death after six months.

The case is unusual because of the age at which the sarcoma developed. The oldest previous patient reported by Gvistel and Yanker, was seventy-eight years of age. Usually the average age at onset of Paget's disease is about forty-six, and the age of sarcomatous degeneration is about fifty-eight.

Although it is difficult to state with assurance, about 8 per cent. of patients with Paget's disease present signs of sarcoma. Pathological fracture, not common in association with primary sarcoma, is the first sign of sarcomatous degeneration in about one-third of the cases. In all, the roentgenographic findings are distinctive.

The sarcoma arises almost exclusively in bone showing the characteristic pagetoid appearance. Thus it is common to find the picture of Paget's disease with presarcomatous degeneration and with true tumor formation in the same area. In those instances where the sarcoma is metastatic, only the one histological picture is present. Because of this, the authors are of the opinion that the multiple localization of sarcomata in Paget's disease is evidence of polyosseous sarcomatous degeneration, rather than of degeneration with metastatic spread of the tumor. In most instances, the prognosis is bad. The extreme life expectancy after discovery of the sarcoma is about two and one-half years, with an average expectancy of one year.—*Henry Milch, M.D., New York, N. Y.*

LA PROBLÈME DE L'OSTÉOCHONDRITE DISSEQUANTE (THE PROBLEM OF OSTEOCHONDRITIS DISSECANS). J. A. Mathez. *La Presse Médicale,* 54: 211–212, 1946.

The author undertakes to support the thesis that osteochondritis dissecans is traumatic in origin. He shows that the process occurs at the most prominent part of the curvature of the condyle. It always begins in the bone, and the cartilage covering it may remain intact for a considerable length of time. The bony surface is always convex. This outline is mathematically determined by the contour of the condyles, and is not related to interference with blood supply. In the opinion of the author, osteochondritis dissecans is to be looked upon as a fracture, caused by vibration.—*Henry Milch, M.D., New York, N. Y.*

LUXO-FRACTURA DE LA ARTICULACIÓN DE LISFRANC (FRACTURE-DISLOCATION AT LISFRANC'S JOINT). Augusto Wybert y Juan Alberto Pérez Rovira. *Revista de la Asociacion Medica Argentina,* 59: 481, 1945.

The authors report the case of a twenty-year-old male, whose foot was crushed and who was hospitalized about two weeks after injury. Examination disclosed a swelling on the dorsum of the foot, in the region of the tarsometatarsal joint. The longitudinal arch was depressed, the outer border of the foot was concave and shorter than on the opposite side, and there was definitely localized tenderness. The roentgenogram disclosed a fracture of the internal cuneiform of the base of the second metatarsal, with a lateral dislocation of the fore part of the foot. Manipulation under anaesthesia and traction with wires through the calcaneus and through the metatarsal heads was unsuccessful. Reduction was accomplished after open operation, levering the fractured second metatarsal into place.

The authors point out the important role of the second metatarsal head. Although it was originally believed impossible for dislocation to occur without fracture of this bone, this has since been found to be untrue.—*Henry Milch, M.D., New York, N. Y.*

Artrodesis del hombro en la parálisis infantil. Técnica personal (Arthrodesis of the Shoulder in Infantile Paralysis). Valentín C. Girardi. *Revista de la Asociacion Medica Argentina*, **59**: 485 1945.

Scapulohumeral arthrodesis, first devised by Albert in 1879, was popularized by Vulpius in 1898. In general, the extra-articular type of operation is reserved for the tuberculous osteo-arthritis, while the intra-articular operation and the combined operation are employed for the paralytic cases. The fusion operation is to be preferred to muscle-transplant or nerve-grafting operations. Fusion in children may be performed as early as the sixth to ninth years, but the optimum age is between ten and twelve years. Following the recommendations of The American Orthopaedic Association Committee, the author advises fusion in right-angled abduction with the arm in 35 degrees of flexion and 25 degrees of internal rotation.

The many different types of fusion operation which have been recommended are briefly reviewed. The author describes his own technique. The skin incision is made from the region of the acromial tip down to the apex of the axilla. The subcutaneous tissues are sectioned in the same plane. The cephalic vein is tied and cut, if necessary. The deltoid muscle is then opened by a T-shaped incision, the long arm of the T descending along the axis of the humerus. The humerus is exposed and an osteoperiosteal graft, six centimeters by one centimeter, is prepared. The head and the glenoid are then denuded of cartilage. The head is placed in the ideal position and fixed, by means of a Lambotte screw, into the glenoid. The bone graft is then fixed along the anterior aspect of the glenohumeral joint, and the wound is closed.

Immobilization is carried out by means of a previously prepared plaster spica. This is retained for a period of from three to six months, or until the roentgenograms disclose firm bony union.—*Henry Milch, M.D., New York, N. Y.*

El tratamiento del dolor en la artrosis deformante de cadera, por la neurotomía del obturador (operación de Selig) (Treatment of Pain in Deforming Arthritis of the Hip by Obturator Neurotomy: Selig's Operation). Guillermo F. Cottini. *Revista de la Asociacion Medica Argentina*, **59**: 884–891, 1945.

The therapy of coxarthritis is primarily the treatment of pain. The limitation of motion is of secondary consequence. Many different types of treatment have been recommended, but the neurotomy suggested by Selig seems to have special value, particularly in patients over sixty, in whom other procedures are contra-indicated.

The operation is based upon the fact that the hip joint is supplied by sensory nerves from the sciatic, the femoral, and the obturator nerves. In many instances simple section of the obturator nerve suffices; in other cases, additional section of the sciatic or the femoral branches, as well as drilling operations, may be necessary to bring about results.

The operation is extremely simple and has no contra-indications. The author performs it under spinal anaesthesia and prefers to divide the obturator nerve on the pelvic side. The approach is made through an incision splitting the rectus muscle, and has been performed in eighteen cases.

In eleven of these cases, follow-up results have been obtained. Of these, five were excellent, two were good, and four were unsuccessful. In these four cases, only the obturator nerve was divided.

The author believes that the procedure exerts its best effects in patients who have contracture of the adductors. It would appear, therefore, that part of the effect is of anaesthetic origin and part is due to conversion of the adduction contracture.—*Henry Milch, M.D., New York, N. Y.*

Condro-osteomas múltiples: Exostosis metafisiales—exocondrosis osteogénica (Multiple Osteochondromata). Conrado Zuckermann. *Revista Mexicana de Cirugía, Ginecología y Cáncer*, **13**: 169–186, 1945.

This is a case study of a nineteen-year-old boy with multiple osteochondromata involving the lower tibia, lower femur, upper tibia, and upper fibula. The tumor just below the knee was first noticed after a minor injury; it was excised and the pathological sections carefully studied. A review of the pathological findings revealed fibrous connective tissue, cartilaginous tissue, and bony tissue.

The author gives an excellent review of the subject of multiple osteochondromata. These tumors invariably originate at the cartilage plate at the end of the long bone, in the metaphysis. They rarely become transformed into blastomata. They occur more frequently in males than in females, and there is a definite hereditary tendency. They are frequently multiple and sometimes symmetrical. The author states that occasionally these tumors are noted in the flat bones, also. A bursa sometimes forms over the tumor. The differential diagnosis is not too difficult, and roentgenograms of many of the long bones should be taken to ascertain whether or not the tumors are multiple. No treatment is known for these tumors except excision, and this should be done if the location, size, or pressure symptoms warrant it.

This article is an excellent review of the subject of osteochondromata. It is well illustrated with reproductions of roentgenograms and microscopic slides.—*Louis W. Breck, M.D., El Paso, Texas.*

LES MALFORMATIONS DE LA ROTULE DANS LA GENÈSE DE LA LUXATION HABITUELLE OU CONGÉNITALE DE LA ROTULE (MALFORMATION OF THE PATELLA IN THE ETIOLOGY OF HABITUAL OR CONGENITAL LUXATION OF THE PATELLA). P. Swynghedauw et E. Laine. *Revue d'Orthopédie et de Chirurgie de l'Appareil Moteur*, **31**: 25–35, 1945.

Attention is called by the authors to a congenital deformity of the patella which can easily be diagnosed on axial x-rays of the patella. There is then a widening of the patella in the anteroposterior plane, and also a change in the medial portion of the patella, which becomes shorter and more globular.

In the absence of this roentgenographic finding, the treatment of habitual dislocation requires the usual capsular procedures or the transplantation of the tibial tubercle. In the presence of a congenital deformity of the patella, however, the authors consider a patellectomy as the treatment of choice.—*Emanuel B. Kaplan, M.D., New York, N. Y.*

INTERVERTEBRAL DISC LESIONS. GENERAL DISCUSSION AND CONSIDERATION OF TREATMENT IN MILITARY SERVICE. Exum Walker. *Southern Medical Journal*, **38**: 832–834, 1945.

Sciatic radiation due to root pain, associated with paraesthesia, is the chief diagnostic symptom in lesions of the intervertebral disc. This pain can be produced by direct stimulation. The sensation of the foot "going to sleep" could result from ischaemia of a section of the nerve root, and consequently a physiological neural block. Besides the operation upon the disc, additional relief is obtained in certain cases by section of the sensory portion of the nerve root involved. Some surgeons advocate fusion of the vertebrae, but this does not always give relief, and prolongs the operation and the convalescence. Conservative treatment should be used in the majority of cases.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

TREATMENT OF PERIPHERAL NERVE INJURIES. Arthur M. Pruce. *Southern Medical Journal*, **39**: 289–291, 1946.

Two new diagnostic procedures in peripheral-nerve injuries have been introduced: the neurodermometer (Richter) and a device for the determination of galvanic tetanus (Pollock). The former is an objective method for determining the area of anaesthesia, independent of the patient's cooperation. With the use of the latter, evidence of muscle re-innervation is shown much earlier than by standard methods. Both of these techniques are as yet in the formative stage.

The paraffin bath is very useful. Whirlpool baths are followed by ultraviolet radiation to improve the circulation and the condition of the skin. Exercises and galvanic stimulation are used. This report is from the service at Lawson General Hospital, Atlanta.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

SPINAL FUSION FOLLOWING REMOVAL OF INTERVERTEBRAL DISK. Edward L. Compere. *Southern Medical Journal*, **39**: 301–306, 1946.

Spinal fusion alone has relieved many patients with low-back pain, but some continue to have sciatic pain after this operation. Many patients have been relieved of their pain by removal of the intervertebral disc, without fusion of the spine. Some are not relieved by this operation, or later have a return of their pain. The anatomy and function of the intervertebral disc are discussed. In both animals and humans, after removal of the disc, arthritic changes tend to develop, both in the articular facets and along the margins of the vertebrae. During the past five years the author has combined removal of the ruptured disc with fusion of the laminae by the Hibbs technique. He uses many chips and splinter grafts to get a solid fusion of the vertebra above and the one below the involved disc.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

TOWEL CLIP FIXATION OF FRESH CLAVICULAR FRACTURES. Milton C. Cobey. *Southern Medical Journal*, **39**: 307–311, 1946.

The method of reduction and fixation of the clavicle with towel clips was in use at Johns Hopkins Hospital in 1934. The patient is given a general anaesthetic and placed on a fracture table with a single support under the shoulders. The area of the clavicle is prepared for surgery. Small stab wounds are made. Carefully the points of the clips are inserted into the bone on each side of the fracture, about one inch from the fracture line. The handles should overlap after reduction, if possible. The fluoroscope may be used, but is not essential. Small colloidin dressings are applied, and the handles are tied together. Plaster-of-Paris may be molded about the handles for fixation. A jacket type of plaster cast is applied, without a spica. The handles are not fixed to the plaster cast. Patient may be ambulatory.

This method has been used over a period of eleven years. No complications have occurred. It has been used in only 14 per cent. of cases, and then only after conservative methods have been tried. The author is opposed to open operations on the clavicle.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

THE MOLDED BONE GRAFT. Arthur J. Barsky. *Surgery*, **18**: 755–763, 1945.

Barsky advocates the use of molded bone grafts in selected cases. The method, which he has used in fifteen cases, is carried out as follows:

The loss of contour is studied carefully, and roentgenograms are taken. A plaster study model is

prepared, which should include the normal side as well as the area of defect. With wax, the area of defect is built up on the plaster cast. The mold or splint is made of sheet lead, one thirty-second of an inch thick, and it is pressed into shape over the restoration and onto the normal tissue beyond.

The recipient area is prepared first, and then thin shavings of dense bone and large quantities of cancellous bone are taken from the crest of the ilium. The cancellous bone is cut into pieces a few millimeters in size and is deposited in the cavity. Over this are placed the thin shavings of bone, immediately beneath the surface of the skin. After closure has been completed, the molded splint is applied, with a thin layer of dental modeling compound between it and the skin. A pressure bandage is then applied.

The mold is left in place for four or five days, but may be removed temporarily in order to remove sutures.

This type of graft is advocated only as a contour restoration for defects in the skull and bones of the face, and is not recommended for bones which bear weight or are subjected to functional stress.

FISSURES OF THE ARTICULAR CARTILAGE OF THE PATELLA. OCCURRENCE IN MULTIPARTITE PATELLA. Charles J. Sutro. *Surgery,* **19**: 251–266, 1946.

Degenerative lesions of hyaline cartilage occur on the patella in much the same way that they do upon other articular surfaces. Their presence may be characterized by areas that are soft and spongy, which have been described as chondromalacia patellae, or by cracks and fissures in the articular cartilage. Trauma, especially a direct blow which drives the patella against the articular surface of the femur, is probably the primary etiological factor. Repeated minimum traumata produced in ordinary daily activity must play some role, however. The symptoms accompanying fissures of the articular cartilage are often acute, and occur shortly after a specific injury or after unusual physical exertion. The patient may complain of sharp pains, instability, temporary locking, enlargement of the knee region, and inability to bear weight. Later the symptoms may be described as "locking"; loud crepitations are also a complaint. When the examining physician moves the patella back and forth or up and down against the articular surface of the femur, the patient may complain of severe pain; crepitation is often felt.

The author has reported fifty-eight cases. The patients with relatively mild symptoms were treated with the usual conservative measures of protection, heat, and massage; they were advised to avoid all exercises, including marching, walking, and dancing, in so far as possible, for three or four months after the injury. When the symptoms persisted in spite of conservative treatment, surgery was advised. In nine of the eleven cases operated upon by Sutro, only the injured portion of the cartilage was removed. In only one case was the entire patella excised.—*Edward L. Compere, M.D., Chicago, Illinois.*

THE USE OF DRAINAGE IN OPERATIONS ON THE SPINE. Leo S. Lucas and Joseph H. Gill. *The Western Journal of Surgery, Obstetrics and Gynecology,* **53**: 379–380, 1945.

It is usually recognized that the chief complication of operations on the spine is hematoma formation, inasmuch as they may lead to secondary infection by retrograde and hematogenous routes, or to chronic sinus formation and osteomyelitis of the spine. To avoid this complication, the author inserts one small cigarette drain in the floor of the wound before the wound is closed tightly. This is left in for exactly twenty-four hours. In a series of 104 cases in which this method was used, there was no case of hematoma, chronic sinus formation, or infection of the deep structures.—*F. Harold Downing, M.D., Fresno, California.*

CHRONIC SCLEROSING OSTEITIS. Henry W. Meyerding. *The Western Journal of Surgery, Obstetrics and Gynecology,* **53**: 413–421, 1945.

In a period of thirty-two years—from 1912 to 1945, inclusive—eighty patients with chronic sclerosing osteitis have been seen at the Mayo Clinic. This represents a 2 per cent. incidence in 4,000 cases of osteomyelitis. The outstanding symptom is persistent pain of varying severity, which may be present for months or years and usually becomes worse at night. It is deep-seated, and is usually located in the shafts of the long bones. The roentgenographic findings are significant. They show a localized area of dense sclerotic bone with a region of lesser density, often round or oval. There is considerable proliferation of the cortical bone, with swelling of the cortex, which is sometimes mistaken for malignant osteogenic sarcoma or syphilitic periostitis. The regions may partially involve the entire cortex for a distance of several inches, or they may partially or completely close the medullary cavity and produce a dense, spindle-shaped mass in the shafts of the long bones.

The treatment is surgical, and the extent of the operation depends upon the degree of involvement. An attempt has been made to saucerize the involved area. Multiple drilling did not prove satisfactory. The wound is sprinkled with sulfathiazole and closed without drainage in the majority of cases. If external support is required, plaster casts are used. Of fifty patients traced from two to thirty-one years, thirty-four (68 per cent.) obtained complete relief from symptoms; seven (14 per cent.) obtained partial relief, and nine (18 per cent.) had had no improvement.—*F. Harold Downing, M.D., Fresno, California.*

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Boletín del Colegio Médico de la Habana (Cuba), **9**: Núm. 6, 1946.
Boletines de la Sociedad de Cirugía de Rosario (Argentina), **12**: Nos. 5, 6, 7, y 8, 1945; **13**: Nos. 1 y 2, 1946.
Brasil Médico-Cirúrgico (Rio de Janeiro), **8**: No. 1, 1946.
The Bulletin of the U. S. Army Medical Department (Carlisle Barracks, Pennsylvania), **6**: Nos. 1 to 4, 1946.
Harper Hospital Bulletin (Detroit, Michigan), **4**: No. 1, 1946.
Hospital for Joint Diseases (New York, N. Y.), Annual Report, 1945.
The Johns Hopkins University, School of Hygiene and Public Health, Catalogue Number, 1946–1947.
Médica (Matanzas, Cuba), **5**: Núms. 3 y 4, 1946.
The National Foundation for Infantile Paralysis, Inc. (New York, N. Y.), Poliomyelitis and Hospitals, 1946.
The Physiotherapy Review (New York, N. Y.), **26**: Nos. 4 and 5, 1946.
Radiography and Clinical Photography (Rochester, New York), **22**: No. 1, 1946.
Revista Médica Municipal (Rio de Janeiro, Brasil), **7**: Núms. 1, 2, e 3, 1945.
Sociedad de Cirugia de Cordoba (Argentina), Boletines y Trabajos, **6**: No. 7, 1945; **7**: Nos. 1, 2, 3, y 4, 1946.
United States Public Health Service (Washington, D. C.), The Journal of Venereal Disease Information, **27**: Nos. 7, 8, and 9, 1946; National Institute of Health, Bulletins Nos. 185, 186, and 187, 1946; Public Health Reports, **61**: Nos. 26 to 41, 1946; Supplements Nos. 180 and 190.

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